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OF THE

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The Society as a body is not responsible for statements made by individual members.

COUNCIL OF THE SOCIETY

(Under whose supervision this number is published).

Rear Admiral J. R. EDWARDS, U. S. N. — Engineer-in-Chief R. S. GRIFFIN, U. S. N.

Captain B. C. BRYAN, U. S. N. — Commander S. S. ROBISON, U. S. N.

Lieutenant Commander H. C. DINGER, U. S. N.

THE AMERICAN SOCIETY OF NAVAL ENGINEERS —ITS ORIGIN, SCOPE AND PURPOSE.

"A QUARTER OF A CENTURY IN THE EXISTENCE OF THE ORGANIZATION."

BY REAR ADMIRAL JOHN R. EDWARDS, U. S. NAVY, MEMBER.

INTRODUCTORY.

Inquiry has frequently been made by individual members of the Society concerning its origin and purpose. The by-laws of the organization give no information as regards either feature, and, even when referring to the initial number of the first volume of the Journal of the Society, it is noticeable that there is no mention made whatever as to the special or impelling reasons for the publication of the periodical. The third page of the cover of the initial number of the Journal, however, contains the names of the Officers and Council of the Society.

OFFICERS WHO ORGANIZED THE SOCIETY.

Fortunately for the interests of the organization, the personal diary of Rear Admiral G. W. Baird, U. S. N. (Retired), contains an entry that gives to the members of the Association some interesting history concerning its organization. The notes and recollections of this officer, who was subsequently elected a President of the Society, have been utilized wherever possible in the preparation of this article.

Many of the officers of the old Navy were accustomed to keep a personal diary and to note, when the circumstances were fresh in mind, the most important personal and official events that had happened each successive day. Rear Admiral Baird has been keeping such a diary since he entered the Navy in 1862, and in turning over to the page wherein events of September 30, 1888, are recorded, there is found the following reference to the organization of the American Society of Naval Engineers:

> "The Engineer Officers had a meeting at the Bureau today, at which were present the following officers of the old Engineering Corps: W. S. Moore, A. M. Mattice, W. H. Nauman, F. C. Bieg, G. Kaemmerling, W. H. Chambers, R. S. Griffin and others. The purpose of this meeting was to devise some means for the recording of trial trips and to prepare and read papers pertaining to debatable subjects in naval engineering."

It is a matter of exceeding regret that Rear Admiral Baird's notes did not record the name of every officer who was present at this meeting or at any tentative preliminary assemblage that had been called for such purpose. There is evidence to show that there were also present at the meeting C. H. DeValin, B. C. Bryan, W. H. Allen, Stacy Potts, H. P. Norton, W. D. Weaver, R. B. Higgins, Victor Blue and Ward Winchell. There is some circumstantial evidence to show that there were other officers present at this meeting whose names it has not been possible to obtain.

OFFICERS OF OLD ENGINEERING CORPS WELCOMED ADVENT OF THE SOCIETY.

While Rear Admiral Baird's diary and the unofficial notes of the Association show that at least twenty officers of the old Engineer Corps attended tentative conferences or preliminary meetings in connection with the organization of the Society, it is but just to state that many engineer officers detailed to duty at the various navy yards gave early and cordial support and encouragement to the purpose of forming such an organization. The influence of these officers was undoubtedly a stimulus in the organization of the Society. The personal diary of Chief Engineer Fred G. McKean, U. S. N., shows that about October 23, 1888, a circular letter was sent out by the officers of the Bureau, telling of the proposed effort to organize such a Society. Bearing upon this feature, the books of the Treasurer show that within three months from the time the organization was projected, 102 officers of the old Engineer Corps had not only become members, but had paid the first year's dues. Within a year from the time of the organization of the Society the great bulk of the officers forming the old Engineer Corps of the Navy was comprised within its membership, for by the end of the year 1889 the Society had about 225 members. It may be of interest to recall the fact that it was originally contemplated to have branches of the Society at various naval stations, and such a branch was actually organized at Philadelphia.

NECESSITY FOR SUCH AN ORGANIZATION.

Some very far-reaching results were accomplished by the comparatively small assemblage that gathered at the Department on September 30, 1888, to organize the Society. It should be stated that about 1888 the character and extent of the machinery installations on board battleships had reached a point where it became imperative that fuller recognition should be accorded engineering duty, and therefore it was deemed of importance that some means should be taken to augment

naval engineering efficiency and to promote engineering prestige.

For years previous to 1888 it had been tentatively proposed by individual officers connected with the old Engineer Corps to extend engineering experimental research work and to issue desultory if not regular periodic papers relating to naval engineering advance. While there may have been but little thought previous to that time of forming a distinctly Naval Engineering Society, there was an impelling demand for such action, since there had developed urgent and cogent reasons for bringing within the reach of our naval engineers special and valuable technical information and data that was possessed by individual officers, but which was not available to the service at large. While individual officers of the old Engineer Corps had at times published fragmentary notes and thoughtful articles along special lines which possessed great engineering value, there was but little attempt to collate and classify this information. In special instances some of these professional notes were used as technical text books at the Naval Academy. Even the best of the naval engineering text books used at Annapolis were compilations of lectures and engineering notes that covered a wide domain, rather than well-presented and complete text books relating to distinctly naval engineering matters.

LACK OF ADEQUATE RELIABLE NAVAL ENGINEERING LITERATURE WHEN SOCIETY WAS ORGANIZED.

There were at that period also available to the officers of the Naval Service certain annual and special reports issued by the Bureau of Steam Engineering, some of which contained information of exceeding engineering value. These reports, of necessity, were of limited character and number. It may also be stated that there were available to certain officers some exceptionally valuable reports submitted by the Naval Engineering Experimental Board, of which ex-Engineer-in-Chief B. F. Isherwood was President. The number of copies that were printed and distributed of the reports submitted by the

Isherwood Experimental Board was limited, and therefore this information was not always available either to the cadets at Annapolis or to the junior engineer officers of the Service.

Even important information and data that had been submitted by some of the former Engineers-in-Chief of the Navy had not been incorporated in the reports of the Secretary of the Navy. Among other reasons ascribed for such action upon the part of the Department was the fact that this information in part was purely technical and did not relate wholly to naval engineering matters.

VALUABLE PROFESSIONAL BOOKS THAT HAD BEEN WRITTEN BY OFFICERS CONNECTED WITH THE BUREAU OF STEAM ENGINEERING.

The authoritative, remarkable and classic reports of Engineer-in-Chief Isherwood, the excellent treatise of Engineer-in-Chief King concerning the naval ships of foreign countries, together with the standard reference text book of Engineer-in-Chief Shock on Marine Boilers, bore testimony to the engineering literary talent that was comprised in the old Engineer Corps.

OFFICERS OF THE OLD ENGINEER CORPS WHO RENDERED DISTINCT SERVICE IN PROMOTING ENGINEERING ADVANCE.

As a translator of foreign technical text books and along the lines of indexing and classifying engineering literature, Chief Engineer F. G. McKean has probably had few superiors in the Navy. By reason of his technical knowledge, power of presenting a case, and his application of purpose, the work done by this officer along engineering lines in the rehabilitation of the Navy, if known in its fulness to the service at large, would justly place him as one of the strongest men of the old Engineer Corps.

Included among the best technical translators that the Navy has possessed there should be mentioned the names of Rear

Admiral C. W. Roelker and Captain Emil Theiss as translators from the German. The translation of Mr. Isherwood from the French probably represents the best line of work of this character that has ever been done by a naval officer. There were other officers of the old Engineer Corps—men like Engineer-in-Chief C. W. Loring, Chief Engineer Robert Crawford, the late George Westinghouse, Professor R. M. Thurston, David S. Greene, Rear Admiral David Smith, Rear Admiral S. L. P. Ayres, Chief Engineers Herschel Main, and Robert Crawford, and Passed Assistant Engineer J. C. Kafer, who rendered distinct and important service in advancing engineering prestige. It was therefore thoroughly recognized by those interested in the organization that if the Society should issue a quarterly publication it might be anticipated that there would be prepared or translated professional papers on marine engineering matters that would be regarded throughout the engineering world as of high order, and such has proved to be the case.

In reviewing either the work of the old Engineer Corps, or that of the American Society of Naval Engineers, the masterly work of Captain F. M. Bennett, U. S. N., "The Steam Navy of the United States," should be consulted and be regarded as a standard reference book upon matters pertaining to naval engineering development in the United States. This authoritative and excellent work likewise shows forth the character and ability of the remarkable men who directed and controlled engineering affairs for the early years during which the old Engineer Corps was in existence.

NAME OF SOCIETY.

At the meeting held on the 30th of September, it became evident that the dissemination of information relating to naval engineering advance was an urgent necessity to the education and development of the future officers of the Engineering Corps of the Navy. Mr. A. M. Mattice, who was then an officer of the old Engineer Corps, proposed that a Society

should be organized, whose purpose it would be to promote naval engineering prestige and efficiency, and that it should be called the "American Society of Naval Engineers." It is to this officer of the former Engineer Corps, therefore, to whom the Society is indebted for its name. It is of interest to note that Rear Admiral Baird presided at this meeting, and that his zeal and desire to organize such a Society was of such deep personal nature that it had a very far-reaching influence in arousing the interest of all connected with the Bureau in promoting such purpose. The present Engineer-in-Chief, R. S. Griffin, who was then a Passed Assistant Engineer in the Navy, was Secretary of the conference. During the course of the meeting so much interest was aroused that it was then and there determined to build up such a Society, to issue a quarterly journal, and to promote naval engineering efficiency and advance by every possible means consistent with their duties as naval officers.

EDITORSHIP OF JOURNAL.

Ex-Engineer-in-Chief Isherwood was requested to edit the Journal; but, as he was then 65 years of age and was engaged in some very important engineering research work, he was reluctantly compelled to decline the editorship of the publication. He did, however, prepare the first contribution to the first number of the Journal and which was issued February, 1889. After careful consideration of the question of editing the Journal, it was, however, found necessary to assign to the officer serving as Secretary and Treasurer, the Editorship of the magazine.

PRINTING OF THE JOURNAL.

The initial, as well as every succeeding number of the Journal that has been issued, represents the skillful, intelligent and conscientious work of R. Beresford, of Washington, D. C. The successive editors of the Journal have all been keenly

appreciative of the personal pride and interest that has animated Mr. Beresford in getting out the publication, and it is, therefore, with exceeding pleasure that this occasion is taken to bear tribute to this work.

In attempting to prepare even a brief outline of the origin, scope and purpose of this Society, it has been found necessary to bring somewhat into prominence either the work done during previous years by individuals in promoting engineering advance, or certain events that had a very determining influence in the upbuilding of an efficient steam navy. The references, therefore, that will be made to individual officers have been found essential in bringing more clearly to view the impelling reasons and trend for the organization of this Society.

FIRST PRESIDENT AND SECRETARY OF THE ORGANIZATION.

Chief Engineer N. P. Towne, U. S. N., one of the ablest officers of the Engineer Corps, was elected as the first President of the Society, and Passed Assistant Engineer R. S. Griffin as Secretary. The latter officer volunteered to take up the work of editing the Journal, and it is fitting that it should be made a matter of record that not only this officer but his immediate successor, Passed Assistant Engineer W. M. McFarland, carried on this additional work for those two years without any compensation or emolument. In 1891 the work of the Secretary-Treasurer had increased to such an extent that the Council of the Society voted to allot a moderate salary to the Secretary-Treasurer as a gratuity for the important service performed by him.

Through the personal work of the Secretary the younger engineer officers of the Service were induced to join the Society, and all Members and Associates were invited to prepare articles and monographs for the Journal. The work of interesting the older engineer officers in developing the Society as well as in arousing interest in the Journal was delegated to Chief Engineer G. W. Baird.

VARIOUS PRESIDENTS AND SECRETARIES OF THE SOCIETY.

Year.	*President.*	*Secretary-Treasurer.*
1889	Chief Engineer Nathan P. Towne.	P. A. Engineer R. S. Griffin.
1890	Chief Engineer Nathan P. Towne.	Asst. Engineer W. M. McFarland.
1891	P. A. Engineer G. W. Baird.	Asst. Engineer Emil Theiss.
1892	Chief Engineer David Smith.	P. A. Engineer W. M. McFarland.
1893	Chief Engineer H. Webster.	P. A. Engineer W. M. McFarland.
1894	Chief Engineer H. Webster.	P. A. Engineer R. S. Griffin.
1895	Chief Engineer Jas. H. Perry.	P. A. Engineer R. S. Griffin.
1896	Chief Engineer E. D. Robie (Ret.).	P. A. Engineer F. C. Bieg.
1897	Chief Engineer David Smith.	P. A. Engineer F. C. Bieg.
1898	Chief Engineer H. Webster.	P. A. Engineer W. M. McFarland.
1899	Chief Engineer H. Webster.	Chief Engineer A. B. Willits.
1900	Commander H. Webster.	Lt. Commander A. B. Willits.
1901	Commander C. W. Rae.	Lieutenant B. C. Bryan.
1902	Commander C. W. Rae.	Lieutenant C. W. Dyson.
1903	Lieut. Commander W. M. Parks.	Lt. Commander John R. Edwards.
1904	Rear Admiral John D. Ford.	Lieutenant M. E. Reed.
1905	Commander A. F. Dixon.	Lieutenant W. W. White.
1906	Commander A. B. Canaga.	Lieutenant C. K. Mallory.
1907	Commander B. C. Bryan.	Lt. Commander T. C. Fenton.
1908	Commander R. S. Griffin.	Commander T. C. Fenton.
1909	Rear Admiral J. K. Barton.	Lieutenant H. C. Dinger.
1910	Engr-in-Chief H. I. Cone.	Lieutenant H. C. Dinger.
1911	Engr-in-Chief H. I. Cone.	Commander U. T. Holmes.
1912	Captain R. S. Griffin.	Lieutenant John Halligan, Jr. Lt. Commander E. L. Bennett.
1913	Captain R. S. Griffin.	Lieutenant O. L. Cox.
1914	Rear Admiral J. R. Edwards.	Lt. Commander H. C. Dinger.

THE INFLUENCE OF ENGINEER-IN-CHIEF ISHERWOOD IN PROMOTING ENGINEERING ADVANCE.

There are some cogent and special reasons why no attempt should be made at this time to tell of the incomparable service rendered by ex-Engineer-in-Chief Isherwood in contributing to naval engineering prestige and advance. The writer has no hesitation in stating that since machinery was installed as a propelling power on board naval ships probably no officer of any country has done as much as this remarkable man in advancing naval engineering interests. In brief, it may be

said it was primarily the work of this officer that contributed most to naval engineering development, and that was the impetus for the formation of this Society.

ENCOURAGEMENT AND ASSISTANCE RENDERED BY ENGINEER-IN-CHIEF MELVILLE.

Engineer-in-Chief George W. Melville, who was then Chief of the Bureau of Steam Engineering, from the inception of the organization, became exceedingly interested in the work and purpose of the Society. In every possible manner consistent with his official position as Engineer-in-Chief he urged former and present officers of the Naval Engineer Corps to interest themselves in developing and promoting the purpose of the organization and to make the Journal an authoritative publication as regards naval engineering matters. The Society owes this officer an inestimable debt for the work that he did in the upbuilding of the organization.

EXACTING DUTIES OF THE EDITOR.

There have been cogent and important reasons for electing to the position of Secretary-Treasurer (who is also ex-officio Editor of the Journal) an officer of the active list of the Navy. Since the demand for naval efficiency has been so exacting, and as engineering, in its broad sense, has become such an important factor of naval construction and development, it is essential to our naval prestige and efficiency that we should keep abreast, if not try to keep slightly in advance, of our possible naval foes. In order, therefore, to make the Journal the medium that it should be, in giving the officers of our Navy a practical naval engineering extension course, the duties of the Editor have been of the most exacting and strenuous character. Every officer who has held this office has conscientiously striven to maintain the prestige and reputation of the periodical; but, after according full recognition to all who have been associated with this work, the Society

owes a special debt of gratitude to Rear Admiral Griffin and Mr. Walter M. McFarland, now Vice-President of the Babcock & Wilcox Company, for the far-reaching work done by them while serving as Editors of the Journal. It is regrettable, that the necessarily limited length of this article precludes the members of the Society from being informed in detail of the extent and character of the services performed by them, since it has been of a nature to justly inspire this encomium.

WORK RENDERED BY THE LATE COMMANDER F. C. BIEG, U. S. N., IN PROMOTING THE WORK OF THE SOCIETY.

In reviewing, however briefly, the organization and work of the Society, special mention should be made of the interest manifested and the work accomplished by the late Commander Frederic C. Bieg, U. S. N. Probably no commissioned officer of the old Engineer Corps of the Navy, except ex-Engineer-in-Chief B. F. Isherwood, did more in promoting original naval engineering research work and investigation than was done by Commander Bieg. He was among the first to advocate the establishment of an advanced course of training for junior engineer officers. The suggestion to build and equip a naval engineering laboratory originated with this officer. As regards the value and importance of collating the logs and records of the Bureau, he probably did as much if not more than any other engineer officer to analyze and index the important engineering data contained within these reports and records. The far-reaching influence of the work done by this modest, conscientious and able officer is best appreciated by those who knew of the extent and character of the work done by him, since the retiring nature of the man caused him to subordinate himself at all times in the accomplishment of important purposes. Another important service rendered by this officer was due to his tact, zeal and success in inducing the associates of the Society to interest themselves in the work and purpose of the organization.

THE FAR-REACHING INFLUENCE OF THE WORK DONE BY CHIEF ENGINEER CHARLES H. MANNING, U. S. N., IN PROMOTING NAVAL ENGINEERING DEVELOPMENT.

Among the Instructors at the Naval Academy, in 1871, when the Cadet Engineer course of instruction was revived under conditions that gave intimation to the naval service that the Engineer had become an integral part of the naval organization, was a young Assistant Engineer, who was destined to become a very important factor in promoting naval engineering advance. Probably no other officer connected with the naval service realized so clearly in its fulness as did this officer—Assistant Engineer Charles H. Manning, U. S. N. —the far-reaching influence upon naval efficiency and development that would result from the extension of the curriculum of the Naval Academy to an extent that included the extended scientific training of the naval engineer.

This man did more, than dream a vision, of the great purpose he had often hoped for, and which he now realized would soon be consummated. Although he was one of the Junior Instructors of the Steam Engineering Department, retiring and modest by disposition, and unselfish to the core, yet, in a tactful, progressive and masterly manner, he was the recognized leading factor in rapidly developing and establishing at the Naval Academy, an engineering curriculum that materially changed the whole trend of education in the United States, and even in Europe, along the lines of the Mechanic Arts and Sciences; for it is now recognized that, when the distinct engineering curriculum was abolished in 1882 the course in engineering at the Naval Academy probably surpassed any mechanical engineering course of instruction that had then been outlined at any technological institution of the country.

It has been said that the engineering course of today at the Naval Academy is superior to that of 1881, and along certain lines this may be true. The present engineering course, however, is simply a development of work done in the past,

and represents an expenditure of hundreds of thousands of dollars and the work of many persons. It is, however, the pioneer and the pathfinder who often most merit recognition, since every overshadowing figure in history and every great cause has been preceded by some forerunner or token, and when the matter is viewed from this standpoint, Chief Engineer Manning was the man of all others who blazed the way and contributed most to engineering advance at the Naval Academy.

The Construction Corps of the Navy is substantially indebted to this man for taking the primary steps whereby its officers, recruited from graduates of the Academy, were given advanced training in naval architecture at such great institutions as Glasgow, Paris and Greenwich.

The greatest service, however, that he rendered was his remarkable work in arousing the engineer graduates of the Naval Academy to the duty that they owed to themselves and the country, in demanding that naval engineering should be placed upon an official status commensurate with its important duties as regards the design, construction and operation of the great floating workshops and fortresses comprising the modern fleet.

As a culmination of the far-reaching work that he has done for the Engineer and for Engineering in the American Navy, it must be an ineffable satisfaction to him to know that the Naval Appropriation Bill which became a law June 30, 1914, contained a provision whereby those officers, doing engineering duty exclusively, are now eligible for any shore duty compatible with their rank and grade, to which they may be assigned by the Secretary of the Navy.

Any history of the American Society of Naval Engineers that contained no direct reference to the far-reaching influence that this man had upon the development of engineering progress in the Navy would be lacking in an important essential, and that is in want of appreciation and acknowledgment of the great service rendered to the Navy and the Nation by one

whose modesty, humility and commanding ability endeared him to all his students and shipmates.

THE FAR-REACHING INFLUENCE OF THE LATE REAR ADMIRAL JOHN L. WORDEN, U. S. N., UPON NAVAL ENGINEERING EDUCATION.

With the advent, in 1871, at the Naval Academy, of a Class of Cadet Engineers, it was prophesied that the effort to educate officers for the Engineer Corps of the Navy at Annapolis, would meet with the fate which befell the Class of Cadet Engineers who entered the Naval Academy in 1867. Such would undoubtedly have been the case, if it had not been the good fortune of the Navy and the Nation that Commodore John L. Worden, U. S. N., should have been Superintendent of the Academy about the period when such training of Engineers was planned and revived.

It appears strikingly significant, if not providential, that Commodore Worden, who commanded the *Monitor* in her historic fight with the *Merrimac,* should have been made Superintendent of the Naval Academy in 1869, and therefore possessed in 1871 an intimate knowledge as to the capabilities of the Institution at Annapolis to undertake the work of training naval engineers.

No officer who ever held a commission in the American Navy had a higher respect and deeper affection for the customs of the sea, the traditions of the sailing frigate, and the romance of the old ships-of-the line than Commodore Worden. Of the great Naval Commanders who figured in the Civil War, the hero of the *Monitor* and Admiral Farragut were probably the first to recognize in its fulness the fact that with the advent of the armor-clad vessel, there had gone, and gone forever, the clewlines, the buntlines, the reef-tackles and the jib halliards of the age of sail. It was clear to these men, and they gave expression to the fact, that the seas of snowy canvas and the forest of yards and masts which had been the pride and the glory of the sailor of a previous genera-

tion, and about which so much folk-lore and romance had been weaved, such inspiring songs composed, and so much history written, had passed away forever, but with their passing, there had come a class of fighting ships which more than ever before would give the control of the world to the nation that controlled the sea.

One had only to come under the personal influence of a silent, resourceful, forceful and commanding character like Commodore Worden to be strikingly impressed with the fact that he was in the presence of an overshadowing leader. While he did nothing to coddle the Cadet Engineers, Commodore Worden made it clear to those who thought otherwise, that the status of the Cadet Engineer at the Academy was to be identical with that of the Cadet Midshipman, and that during his incumbency of the position of the Superintendent, the education of the Cadet Engineer would be given a free and untrammelled test.

It is regrettable that the necessarily limited length of this contribution to the Journal makes it impracticable to tell of the inestimable service rendered by Admiral Worden in promoting naval engineering advance. His name has been worthily placed in the galaxy of commanding figures in American Naval history.

While it is probable that no Naval Officer of any country could, at the close of the Civil War, have checked the inevitable trend towards naval engineering advance, Admiral Worden was among the first to advance such movement. It is therefore eminently fitting that these brief notes concerning the history of the Society of Naval Engineers should record the splendid work that was done by this officer, since the work was of such character as to cause it one of the great contributing causes that led up to the formation of this Society.

SCOPE AND PURPOSE OF THE JOURNAL OF THE SOCIETY.

There was one very important reason why the Society considered that a Quarterly Naval Engineering Journal should be published, and that was to afford its members, scattered

throughout the world, absolutely reliable information concerning engineering progress and advance. About that period it was exceedingly difficult to procure considerable data of such character, for it can well be understood that private individuals and commercial firms, who had conducted, at great expense, important technical investigation and research work, were not ordinarily inclined to make public the data and conclusions of such tests for the benefit of their rivals or for the world at large. It was probably but natural, therefore, that individual and commercial interests, as a rule, should suppress certain information that was not conformable to their expectation and interest, while at the same time they might be keen to herald their successful efforts. Where individuals had been subjected to heavy expense in conducting research work they were fully justified in using the data thus obtained as a means of promoting professional reputations or in advancing the material interests of those who conducted such work.

INFLUENCE AND SUCCESS OF THE JOURNAL.

When those interested in marine as well as naval engineering advance read the first number of the Journal, which contained but seven papers and ninety-six pages, it was realized that the publication was intended to subserve a high purpose, and that this purpose was to afford not only accurate, but complete, information, to the engineering world concerning the trend and progress of naval engineering development. Such periodicals as the "Engineer" and "Engineering," of London, subsequently gave unstinted praise to the publications of the Society. Subscriptions came to the Secretary from many of the leading shipbuilding firms of the world.

At least two or three hundred technical contributions published in the Journal have commanded marked attention throughout the naval and marine engineering world. The official reports of the machinery trials of our naval vessels, as first published in the Journal, are regarded as containing the most reliable data extant as to the coal consumption and

evaporative efficiency of modern warships. The information contained in these special reports constitutes the essential data upon which the machinery of American warships has been designed.

It is a significant fact that, although nearly every shipbuilding engine firm in America, engaged in naval construction, has either gone into the hands of a receiver or has passed some of their annual dividends, the financial losses of these firms, as a rule, have been found to be due to conditions elsewhere than in the building of the machinery. The data and information contained in the Journal of the Society has been no inconsiderable factor in bringing about this satisfactory condition of affairs, since it has probably prevented serious defects in machinery design that would have been of far-reaching consequence when measured from a financial standpoint.

The research work and deductions of Captain C. W. Dyson, U. S. N., as regards the design of screw propellers, stands on a plane that has never been surpassed by any authority on the subject. It has been found, in general, that where the deductions of Captain Dyson have been departed from to any noticeable extent as regards design of propellers for special ships, there has been failure and disappointment of a character that has involved heavy consequential expenditure upon the part of the contractors.

VALUE OF THE JOURNAL IN PROMOTING NAVAL ENGINEERING PRESTIGE.

It ought also be stated that, in the early days of the history of the Society, when our Navy was in a state of development, articles were contributed to the Journal which represented months of effort upon the part of the individual writers, for naval officers about that period had more time than is now available for literary effort. It was likewise unofficially understood that where the Bureau had directed or suggested the preparation of certain papers for publication in the Journal,

such articles might be regarded as expressive of the policy or views of the Bureau upon these matters. It was not surprising, therefore, that the quarterly literary productions of the Society were regarded, as a whole, of great technical worth. In requesting, urging, and even directing, the officers of the old Engineer Corps to prepare such articles, the Society owes an immeasurable debt to Rear Admiral Melville.

About two years ago the Dean of the Naval Engineering School at the great Charlottenburg Laboratory told one of our Members that no technical productions that came to Charlottenburg from any country were more anxiously awaited than the Journal of the Society.

THE WORK OF THE SOCIETY HAS PROMOTED NAVAL EFFICIENCY.

The articles contributed to the Journal have, as a whole, represented the best sincere and thoughtful efforts of their authors. It was realized that what the engineering world wanted was accurate and complete data, so that each individual could form his own conclusions from a study of the information supplied. The accurate and extended reports contained in the Journal, as regards the trial trips of our warships, have undoubtedly been the means of shaping in certain essential respects the trend of naval engineering design. It is a conservative estimate which states that millions of dollars have been directly or indirectly saved to the Government as a result of information published in the Journal of the Society, since many of the volumes are regarded as valuable books of reference and standard authority by every shipbuilding firm which competes for naval work. Information and data, prepared especially for the Journal, have been the indirect, if not the direct means of increasing the endurance, promoting the efficiency, augmenting the safety, and reducing the cost of operation of the varied and extensive machinery installations of our naval vessels.

CRITICAL PERIODS IN THE HISTORY OF THE SOCIETY.

There have been two periods in the history of the Society when considerable concern was experienced as to the future of the organization. It was considered probable in 1898 that, with the passage of the Personnel Bill, naval engineering prestige would materially decline, and that it would be difficult to maintain the Society along the distinct lines upon which it was organized. While there resulted from the enactment into law of the Personnel Bill a number of withdrawals of the Active Members there was an increase in the Associates which more than made up the decline in the active membership.

In 1908–1909, when naval engineering efficiency and prestige seemed threatened, it was again believed by those most interested in the organization that another crisis had been reached in the history of the Society. The banquet that was given in 1909, in Washington, undoubtedly had a very material effect in overcoming the apprehension that existed at that period concerning the future of naval engineering in the American Navy. As an outcome of that banquet the interest of various naval administrative and legislative officials was aroused to the existing engineering condition of affairs, and an impetus was given to engineering prestige that has had a beneficial effect even up to the present time.

OBLIGATION AND DUTY OF JUNIOR OFFICERS TO CONTRIBUTE ARTICLES TO THE JOURNAL.

It should be stated, for the information of the junior officers of the Service who are members of the Society, as well as for our associate members, that the Council of the organization has decided to pay more liberally for accepted contributions, since it is desired to enhance the value of the Journal as a reference work along naval engineering lines. The literary training and experience that a young officer acquires in preparing technical articles for the Journal ought to prove of professional benefit to him, for the manner in which technical

information is collated and presented counts for much in determining the influence and value of official reports upon engineering matters. Those officers, in particular, who have been given post-graduate instruction along naval engineering lines, ought to be frequent contributors to the columns of the Journal.

The future of the Journal must largely depend upon the extent and character of the professional contributions that may be submitted by the junior officers of the Service. Commendable as may be the purpose of the younger officers of the Service in supporting every publication or periodical that deals directly with naval affairs, those interested in naval engineering development should consider it a privilege, if not an obligation, to give special support in maintaining the Journal of the Society as one of the authoritative periodicals along naval engineering lines.

SOCIETY WORTHY OF DEPARTMENTAL ENCOURAGEMENT.

The Society is worthy of the special consideration of the Navy Department. A room should be assigned in the new Navy Building to the Secretary-Treasurer of the Society (as he is also Editor of the Journal), in carrying on his manifold duties. It is certain that if the Journal should cease to be published there would result a loss of information to the shipbuilding interests, as well as to the Navy at large, that would be of far-reaching character.

PROGRESSIVE OFFICERS ARE KEEN TO PROMOTE THE GENERAL PURPOSE OF SUCH ORGANIZATIONS AS THE UNITED STATES NAVAL INSTITUTE AND THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

The Commissioned Personnel of the Navy are unquestionably benefitted in various ways by the publications of the "United States Naval Institute Proceedings" and the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS. One is well justified in believing that any Commissioned Officer of

the Line who does not take time to give at least a general perusal to the most important contributions contained in one or both of these publications, fails to grasp the far-reaching purpose and benefit of these organizations to the Navy at large as well as of the immeasurable professional service that they can render the individual officer.

It would probably surprise some of the Senior Officers of the Service, if it could be made known to them in its fulness, how far-reaching to their detriment has been the fact that they had not sought membership in either Society. It might be well for some of the junior officers of the Navy to thus give an occasional thought to the material as well as the professional loss in being indifferent and unconcerned as to the work of Service Associations. Can an officer be regarded as progressive who does not take pride and interest in advancing the work of Associations like that of the American Society of Naval Engineers?

EXISTING CONDITION OF SOCIETY.

Fortunately for the interest of the Navy, as well as for that of the shipbuilding firms of this country, the Society is not losing ground, and this fact is not only manifested by the satisfactory financial condition of the organization, but likewise by the enthusiasm and interest that is evidenced in the work of the Society as reflected at the several annual banquets that have been held. The financial condition of the Society, as published in the February, 1914, issue of the Journal, shows that its total assets on December 30, 1913, amounted to $11,038.57. The existing Active and Associate Membership on January 1, 1914, was 753. There are also 363 subscribers to the Journal, and 74 exchanges.

THE ENGINEERING EXPERIMENT STATION.

SOME RESULTS.

By H. G. Bowen, Lieutenant, U. S. Navy, and Leo Loeb, Mechanical Engineer.

No greater advance in naval efficiency was ever made than when in 1908 the Experiment Station was established. In an article by Lieutenant Commander E. J. King, U. S. Navy, "The United States Naval Experiment Station, Annapolis, Md.," Journal of the American Society of Naval Engineers, Vol. XXV, No. 3, August, 1913, the history and equipment of the station were discussed in detail and a general summary given of work accomplished. It is the purpose of this article to show in more minute detail what has been achieved during its brief existence and to trace the intimate connection existing between the station and the fleet.

The question of cost, while not of paramount importance in naval engineering, is entitled to special consideration. The less money spent on equipment and repair, the more is available for new construction.

PACKING.

No other tests have been attended by more gratifying results than those on packing. In this field the experiment station has actually led the manufacturers and pointed out to them how to improve their product.

In 1908 the Navy Department was paying on open purchase requisitions a dollar and twenty-eight cents a pound for high-grade rolled-sheet asbestos packing. In 1912 it paid on contract thirty-five cents a pound for a highly satisfactory rolled-sheet asbestos packing. The price of sheet rubber, wire

FIG. 1.

insertion, has been reduced from fifty-one cents a pound to thirty cents a pound.

It has been conclusively shown by experiments at this station that rubber sheet packing is worthless for high pressures; that no spiral packings, so far tested, have stood up to the requirements, and that for the present, at least, metallic ring packings have no substitute. Where formerly packing was bought on open purchase in a hit-or-miss fashion, now the contract is awarded after test on a basis of durabilty and cheapness, and the packing bill of the Navy Department has been effectively reduced with an actual gain in the quality of the product.

GAGE GLASSES.

Startling results have been achieved in the investigations of gage glasses. The ordinary dipping tests will not indicate the ability of the glass to resist disintegration. As shown by Figure 1 the glass of tubular and reflex gages corrodes in high-pressure steam under usual service conditions, coating the glass with an opaque silicious deposit. If this action continues long enough the glass will dissolve until it fails under pressure. The only certain and efficient method of protecting the gage is to cover the pressure side of the glass with a thin sheet of mica. By this means the glass remains transparent and unattacked as long as the mica covering is intact.

VALVES AND FITTINGS.

Experiments have established the fact that superheated steam does not erode valve fittings but corrodes them, and that monel metal resists this corrosive action better than class "A" or class "B" steel. In all valves tested, however, the valve seats showed the impress of the disc and both were scarred by scale and grit which had been caught between disc and valve on closing. It has been demonstrated for all time that the disc type of bottom blow-off valve is unfit for naval use. Comparative tests are now being made on several of the so-called seatless types, one of which, a Bureau design, has been found highly satisfactory.

LUBRICANTS.

Practical trials of lubricating oils have been made on ice machines and turbo-generators, and the use of those oils which have given unsatisfactory results has been prohibited in the naval service.

In refining oil, sulphuric acid is mixed with the oil as an hydrolizing agent. The acid and moisture are separated from the oil by gravity, but unfortunately the oil may, by combining with the sulphuric acid, form a sulphonated product which is not wholly eliminated. The sulphonated product will break down under sufficient agitation, pressure and temperature, into acid and waxy sludges. To prevent any inferior lubricant being issued to the service all oils are tested to see that they are free from sulphonated products by actually testing them in a specially-constructed machine in which the service conditions of forced lubrication are reproduced and where their action when mixed with salt water may be observed.

CORROSION.

Soda (Na_2Co_3) has been found to have no effect on packings made up of one layer but attacks the binder of packings containing more than one layer, rendering such packing useless by disintegration. It has no harmful effect on gage glasses nor on sound fittings. Soda penetrates rust and opens up old leaks, leaving on the surface dry, white soda crystals. "A soda solution four times as strong as is needed to stop corrosion will have no harmful effect upon a good, tight, properly constructed and properly fitted boiler, using good, thick, one-layer packing material." *

The preservation of boilers from corrosion appears at last to have become something more than guess and conjecture, and one cannot but feel that the subject is on solid ground. Elaborate tests were carried out investigating corrosion of metals following the lines laid down in "Cushman and Gardner" and "Bauer and Heyn." It has been repeatedly shown

* Lyon.

on the feroxyl mount that zinc, at first electropositive to boiler plate, as it changes to zinc oxide eventually becomes electronegative to boiler plate and actually accelerates corrosion. If air be kept out of the boiler water and the water maintained at 3 per cent. normal alkalinity, nothing more can be done. Rust breeds rust, since the iron oxides are negative to boiler plate, and corrosion once started goes on apace; hence a boiler must be kept clean. The tests brought out in addition that:—

(1) A slightly alkaline solution is as corrosive as a neutral one in distilled water.

(2) Alkalinity just too weak to entirely stop corrosion causes pitting.

(3) Any concentration of lime in sea water has very little effect on corrosion.

(4) Mill scale on a plate of steel is as corrosive to steel as copper is in surface contact with the polished metal.

(5) Of two plates electronegative to iron and in surface contact with it, the rougher is the more subject to corrosion.

(6) In sea water wrought iron alone is attacked less than any other iron or any of the steels, but the attack is more local and therefore more dangerous. In this respect ingot iron and pure iron are superior to wrought iron. Cast iron is more subject to corrosion than either wrought iron or pure iron.

(7) There is very little difference between the abilities of good irons and good steels to resist corrosion.

(8) Phospor bronze alone in sea water resists corrosion less, and hot-rolled monel metal more, than any other non-ferrous metals tested.

(9) Copper in distilled water resists corrosion less than any other non-ferrous metal tested.

(10) Graphite in water in contact with steel is corrosive to steel, increasing both the pitting and loss of weight.

The composition of the standard Navy boiler compound as developed from tests at the Experiment Station is based on a phenomenon known to every mechanic, that a polished machine part will remain bright indefinitely when immersed in

a fairly strong solution of sodium carbonate. It remained for the conclusive experiments of Commander Frank Lyon, U. S. Navy, to determine strength of solution which would render all boiler materials non-corrosive. This strength of solution was found to be a 3 per cent. normal solution of chemically pure Na_2Co_3, or a charge of 4.29 pounds of commercial carbonate per thousand pounds of distilled water in the boiler. Any other alkaline applied in the same degree of alkalinity would accomplish the same results. But soda ash is by far the cheapest of the available materials. The compound as now issued to the service has the following composition:

Calcined soda ash (96 p. ct. Na_2CO_3), . .	64.0 to 69.0 p. ct.
Tri-sodium phosphate (96 p. ct. Na_3PO_4), .	15.0 to 20.5 p. ct.
Glucose, ...	1.5 p. ct.
Tannic acid (contained in cutch digested with caustic soda), ...	9.0 to 10.0 p. ct.

The soda alone, while preventing corrosion, would cause priming at high rates of evaporation and the tri-sodium phosphate has been added to reduce the priming. The tannic holds the precipitates, if there be any, in suspension and prevents the adhesion of the scale-forming salts to the heating surfaces, while the glucose tends to prevent cohesion of any sulphate scales. While the proportions of the compound do not represent exactly the ideals of those best versed in the subject, they do form a middle ground between theoretical and practical considerations.

It is a fact which can be verified by experiment that the electropositive element is the one which goes into solution. Therefore, any boiler compound containing a metallic element that is electronegative will cause corrosion of the electropositive element—the boiler. The action of the metallic element in solution may be of assistance as a scale remover due to its expansive property; on the other hand, it may exert its corroding influence unless inhibited by the presence of an alkali. After using a compound with such a metallic element a boiler

FIG. 2.—"CONNECTICUT'S" CRANK SHAFT.

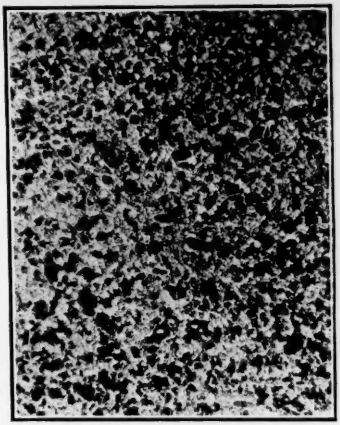


FIG. 3.—"CONNECTICUT'S" CRANK SHAFT.

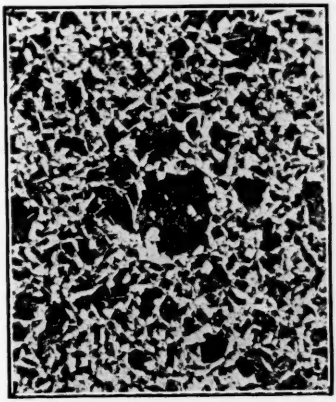


FIG. 4.—"CONNECTICUT'S" PROPELLER SHAFT.

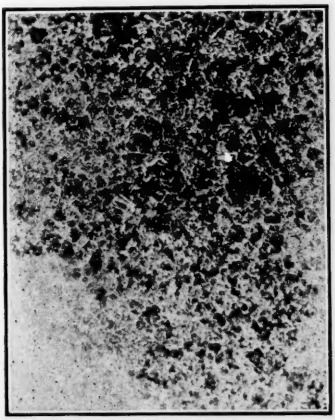


FIG. 5.—"CONNECTICUT'S PROPELLER SHAFT.

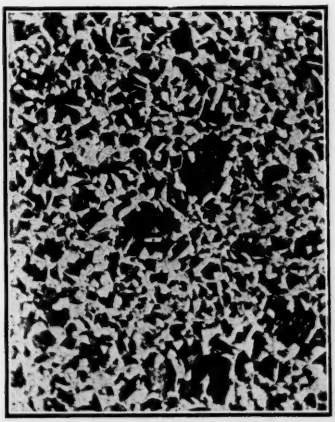


FIG. 6.—"CONNECTICUT'S" PROPELLER SHAFT.

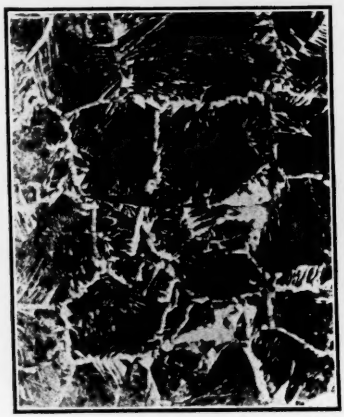


FIG. 7.—CRANK SHAFT FROM *C-4*.

FIG. 8.—CRANK SHAFT FROM *C-4*.

FIG. 9.—CRANK SHAFT FROM *C-4*.

FIG. 10.—MOSHER BOILER DRUM.

FIG. 11.—MOSHER BOILER DRUM. EDGE OF SPECIMEN.

should be washed out and filled up with water made highly alkaline in order to neutralize the effect of any of the metallic element which may remain. Mercury in compounds removes scale and causes corrosion in neutral boiler water but does not remove scale in highly alkaline boiler water.

The Chief of the Bureau of Steam Engineering in his statement before the Naval Affairs Committee summarized the whole status of the prevention of corrosion and boiler compound. He credited the Station with having by its tests prolonged the life of naval boilers by three times, and with having reduced the cost of boiler compound to produce this increased life from 22 cents to 3 cents per pound.

METALLOGRAPHY.

To the Experiment Station belongs the credit of introducing to the naval service metallography, an art which, though still in its infancy, has done more than any other to clear up questions of metallurgical structure and processes of manufacture tending toward the prevention of failure of metal in service. The time is not far distant when every important member of the propelling apparatus will have been subjected to a photomicrographic examination before acceptance. The development of photomicrography at the Station has been attended by results as important as they are startling. Time and time again the blame for the failure of metal has been traced thereby to defects in the manufacture.

Figures 2 and 3 show photomicrographs of the *Connecticut's* broken crank shaft. It will be noted that the crystallographic structure of the metal is not unusual. The slag inclusions of manganese sulphide and iron sulphide are marked. The failure of the metal is attributed to the presence of this slag together with its unequal distribution.

The specific gravity of MnS is half that of steel, so that if the metal had been allowed to stand longer before pouring the MnS would have risen to the surface and could have been skimmed.

Figures 4 and 6 show photomicrographs of a ruptured pro-

peller shaft of the *Connecticut*. Figure 4 shows great patches of ferrite (white) and pearlite. Where ferrite is thus segregated, steel is no stronger than wrought iron. Figure 5 shows the same specimen after being heated in the Station's electric oven to 1,550 degrees F. and then slowly cooled in the furnace. Here the segregation has been replaced by a homogeneous distribution of ferrite and pearlite. Figure 6 shows pronounced segregation and inclusions of manganese sulphide.

Physical tests made on specimens of the shaft after fracture when compared with tests made before fracture show that the shaft had fallen off somewhat in its tensile strength, elastic limit, etc. But the conclusion is inevitable that the annealing temperature—1,425 degrees F.—to which the manufacturers subjected the shaft was too low to produce a grain structure well able to resist alternating stresses. Furthermore the slag inclusions, occurring as they do in the relatively weak ferrite areas, still more reduce the strength of the shaft.

Figures 7 and 9 are photomicrographs of a crank shaft from the *C–4*. Figure 7 shows a crack following the cell walls. The cells are pearlite and the walls are ferrite; the crack is through the weaker ferrite. Figure 8 illustrates coarse-grain size and slag inclusions. Figure 9 is the photomicrograph of a specimen polished but not etched, showing the slag inclusions still more plainly. This crank shaft failed due to impurities and faulty heat treatment. The faulty heat treatment is responsible for the large grain size.

Several water drums of Mosher boilers have been ruptured in service and the cause is made apparent from a photomicrographic examination. In the process of manufacturing the drums are cold-pressed into shape from steel plates and this cold working was not followed by annealing. As a result one would expect segregation and elongated grain. Figure 10 plainly shows segregation of ferrite and pearlite in a Mosher boiler drum. Figure 11 shows the structure near the edge of the rupture. The distorted and elongated grain due to cold working are evident.

FEED-WATER HEATERS.

The testing of feed-water heaters has been one of the Station's most extensive fields of investigation, and it is probable that the work accomplished has contributed more to the exact knowledge of the subject, and developed more reliable data on the transfer of heat in marine feed-water heaters, than all other sources combined.

The first feed heater to be tested was one of Bureau design, proposed for the battleships *Nevada* and *Oklahoma*. The heater submitted consisted of one of the six sections of the heater as actually installed, but it followed the general design as regards size and arrangement of tubes, particularly in the distinctive feature of having the tubes bent into semicircles and expanded at both ends into one composition tube sheet. Thus the passage of the feed through the heater was in a series of semicircular paths. The first series of tests was made to determine the rate of heat transmission in B.t.u.'s per square foot of heating surface per hour per degree Fahrenheit temperature difference between the steam and the water at water velocities from 35 to 171 feet per minute and with shell pressures of 5, 10, 15 and 20 pounds gage. These tests * showed that the heat transfer increased rapidly with the velocity, but that the heating effect varied with the temperature of the entering feed. Several mechanical defects, such as improper baffling, leading to a pronounced erosive effect of steam on the tubes, and weakness of bonnet casting, appeared and were corrected before proceeding further. The collection of air in the steam space was evident. The air gradually blanketed a portion of the heating surface and thus reduced the capacity. This shows the necessity for adequate air vents for the steam space. Since air is heavier than steam under the same conditions of temperature and pressure, these air vents should be located near the bottom of the steam space.

In order to provide data for the design of similar heaters another series of tests were undertaken to indicate the per-

* Journal Amer. Society of Naval Engineers, Vol. XXIV, No. 1, Feb., 1913, page 155.

formance of the apparatus as a multipass heater. At the conclusion of one run the feed water was raised to the temperature of the outlet as shown by the test, and the run repeated with this as an inlet temperature. Thereby the performance of the second pass of such a heater was indicated. This procedure was continued until the feed reached a temperature of about 200 degrees Fahrenheit. The water velocity range was from 130 to 270 feet per minute, equivalent to the flow of water through a single ¾-inch tube of from 1,500 to 3,100 pounds per hour. The water temperature gradients with steam at ten pounds pressure are embodied in the design curves for this heater shown in Figure 12. They furnish a graphical

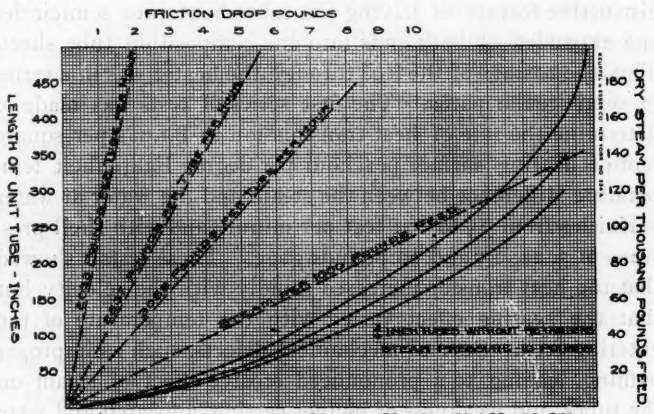


FIGURE 12. FEED HEATER DESIGN CURVES

solution for all ¾-inch tube-heater problems—number and length of tubes, heating surface, friction drop and outlet temperature—when there is known the amount of auxiliary steam available for heating, the quantity of feed water to be heated, the hot-well temperature and the back pressure on the auxiliary line.

To more thoroughly agitate the feed in its passage, the tubes were fitted with spiral retarders consisting of annealed

copper strips $\frac{5}{8}$-inch wide and 0.0268-inch thick twisted to a pitch of six inches. The tubes with retarders give a heating effect of 14 per cent. in excess of plain tubes without perceptible increase in friction. With a circulation of 1,500 pounds per hour the heat transfer is 469 and 389 B.t.u. per square foot per hour per degree mean temperature difference with and without retarders. At a velocity corresponding to flows of 3,000 pounds per hour the rates are as high as 801 and 703 B.t.u.

The requirements of reduced space and weight of ship auxiliaries and more efficient distribution of heating surface have led to the development of the film heater in which the feed passes through the annular ring formed by two concentric tubes and the steam is contained in the space without the larger tubes and within the inner tubes. This original design showed two serious defects: The greatest rate of heat transmission occurred at less than 50 per cent. of rating and the friction drop was so great that it was not possible to circulate the rated feed capacity. With such heaters a ship could not operate under full-speed battle conditions with anything like reasonable steam consumption of feed pumps, as it would be necessary to carry 465 pounds pump pressure to hold 265 at the boilers.

An analysis of the test indicated that the friction drop was principally in the water heads, so the builders undertook to re-design the unsatisfactory features and later submitted an experimental heater composed of four double tubes with spare inner tubes to increase the nominal film from $\frac{7}{64}$-inch to $\frac{3}{16}$-inch. The heater was tested in both a horizontal and vertical position with a considerable advantage in favor of the vertical heater. The poorer performance of the horizontal heater is caused partly by the accumulation of water in the inner tube, but is more particularly due to the insulation of heating surface by a film of air; in fact when air is not removed the capacity falls off 15.6 per cent. in two hours and a half.

The heat transmission reaches the very high value of 1,000 B.t.u. per square foot per degree temperature difference for

either $\frac{7}{64}$-inch or $\frac{3}{16}$-inch film when the water circulated per square foot of heating surface is the same, but the $\frac{3}{16}$-inch film accomplishes the result with 45 per cent. the friction loss of the smaller film and with the further advantage as to duplication of results after repairs or replacements made by ship's force. All heaters, water and oil, now made by this manufacturer have a film thickness of $\frac{3}{16}$-inch.

As an example of the class of work which protects the Government against large expenditures for apparatus based on improper assumptions, there may be cited the test of a freak feed heater consisting of a quadruple-pitch steam helicoid of large diameter pierced with an eight-thread water helix of small diameter. The attempt made in the design was to provide a large conducting surface for the transmission of heat from the steam to the water, and with 16 square feet of heating surface the designer, by some rather remarkable misapplications of a perfectly good theory, expected to heat 46,656 pounds of water per hour from 90 degrees to 190 degrees, whereas under those conditions the water was raised from 90.0 degrees to 98.6 degrees F., a rise of 8.6 degrees F.

BOILER FEED PUMPS.

One of the first machinery tests inaugurated at the Station was the comparative test of a feed pump manufactured at the Boston Navy Yard,* and three commercial pumps. Subsequently three other reciprocating pumps and one centrifugal pump were tested. The tests covered the entire range of piston speeds from twenty-five to one hundred feet per minute and discharge pressures from 250 to 325 pounds gage when handling cold and hot (150 degrees F.) feed. Several of the pumps were eliminated on account of mechanical defects and others on account of excessive steam consumption. The steam consumptions were in certain cases as high as 180 pounds per I.H.P. hour, but several pumps under favorable conditions maintained an economy of 55 to 60 pounds per hour, a very

* Jour. Amer. Soc. of Naval Engineers, Vol. XXIV, No. 1, page 68; Jour. Amer. Soc. of Naval Engineers, Vol. XXIV, No. 4, page 1211.

satisfactory showing for a non-expanding, reciprocating unit operating against a back pressure of 5 pounds gage.

The general characteristics of the reciprocating pumps are shown in Figures 14, 15 and 16. The curves marked A show the results from the navy yard pump. Particular attention is invited to the curves of total discharge in per cent. of piston displacement and steam consumption. The ordinate from the top of the curve sheet to the curves measures the slip in per cent. of piston displacement.

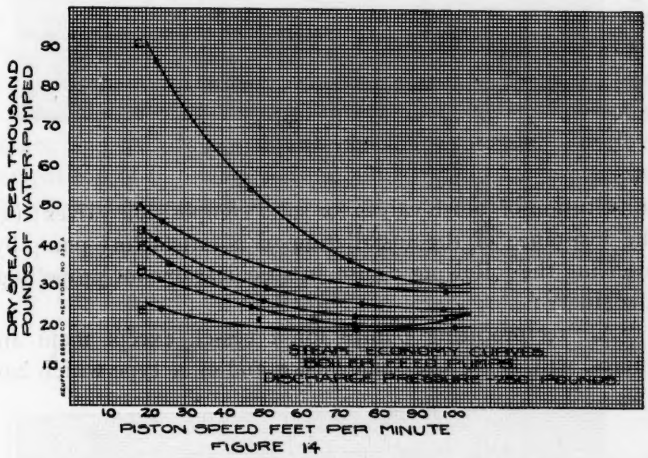


FIGURE 14

The curves of dry steam per thousand pounds of water pumped (figure 14) may be interpreted in still another way. The ordinates are ten times the per cent. of steam consumed by feed pump; that is to say, the pumps tested took from 2.0 per cent. to 4.1 per cent. of the feed water handled to pump against a line pressure of 250 pounds. As there must be included in this calculation the water passing reliefs and packing glands, it is apparent how much the feed pumps contribute to the boiler load.

The pump tests have resulted in (1) the development of a simplex feed pump which is reliable and fairly economical in steam consumption; (2) the reduction of slip losses by the

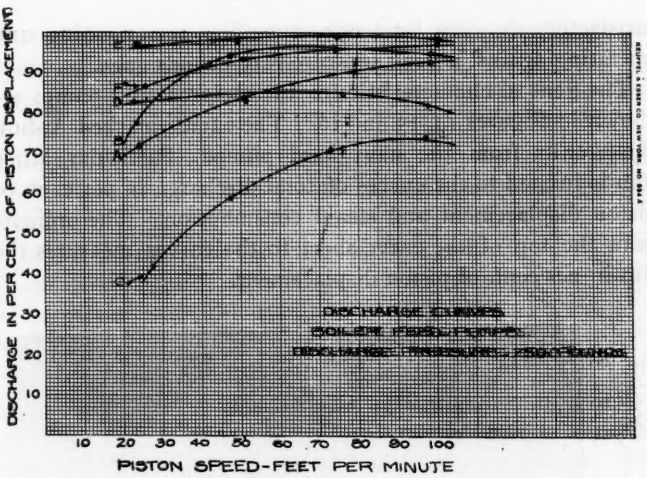


FIGURE 15

substitution of 3-disc valves for solid composition valves; (3) the insurance of the installation of a satisfactory pump by inserting the following clause in specifications for propelling machinery:

"All reciprocating pumps for a vessel, except main air pumps, will be of the same make and of a type which has

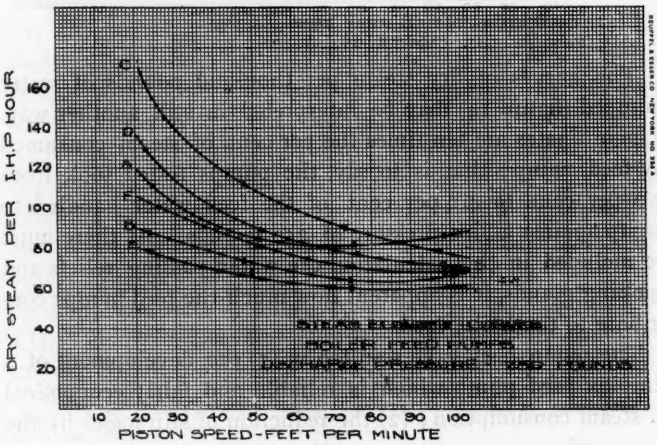


FIGURE 16

satisfactorily passed a test at the Engineering Experiment Station, Annapolis, Md., and has been pronounced suitable for use in naval service, or that has thoroughly demonstrated in the naval service its fitness for the duty to which it is to be applied."

In one instance the Navy Department was saved a considerable sum for patent rights on a design of pump which, while satisfactory at low rate of piston travel, was entirely useless at speeds above 50 feet per minute, the speed at which it would ordinarily operate under full-speed conditions.

A comparison between the vertical, centrifugal and the reciprocating feed pumps is given by the test of a Worthington centrifugal turbine-driven feed pump.* If we assume a piston speed of 75 feet per minute (equivalent to a water rate of 250 gallons per minute) for the centrifugal pump, a comparison of the steam consumption at a discharge pressure of 319 pounds is as follows:

Per cent. of full load.	Steam per 1,000 pounds of water pumped. Simplex reciprocating.	Centrifugal.
33	43.2	55
67	32.9	32
100	27.8	27
133	27.6	26

The advantage lies with the centrifugal pump at high capacities and discharge pressure, but the reciprocating pump has the advantage at lower pressures. A new centrifugal pump is being developed as a result of the experience of the previous tests, and excellent results from the new units are expected.

FORCED-DRAFT BLOWERS.

In order to cope with the stringent requirements of forced-draft blowers on destroyers turbine-driven blowers have been developed. Five different makes of these blowers have been tested at the Station. The results indicate that very little

* Jour. of American Soc. of Naval Engineers, Vol. XXIV, No. 4, p. 1211.

advance is being made in fan design except that the high-speed blowers operating at 1,800 r.p.m. show no decrease in mechanical efficiency over the older types which turned 900 to 1,000 r.p.m. On the other hand, the turbines driving the blowers show a gradual increase in economy, and there are now available three designs of low-powered turbines which operate at reasonable economy against the back pressure of the auxiliary exhaust. With the development of each new type the Station supplies the Bureau of Steam Engineering with basic curves from which can be calculated the proportions of geometrically similar fans for the same service as the one tested but of different requirements as to air pressure, quantity and speed.

SAFETY VALVES.

Two of each lot of safety valves of a vessel or group of similar vessels building are sent to the Station to be tested in accordance with the specifications for propelling machinery thereof, to determine whether the valves reach the required lift of $\frac{1}{10}$-inch with a blowdown of from 5 pounds to 12 pounds. It has developed from these tests that the lift varies with the blowdown, the latter being changed by the adjustment of a huddling ring or similar device. Reducing the blowdown will consequently reduce the lift, thereby reducing the discharge capacity and minimizing feed loss. The required lift is usually obtained with a blowdown of eight pounds.

Following the blowdown and lift tests, the springs are removed and compressed in a testing machine to determine how the working stress compares with the allowable stress of 48,000 pounds per square inch. To accurately determine the working stress a new set of formulae have been developed to include the direct shearing, a factor which can be neglected in many commercial springs, but which in the case of the proportions dealt with in safety-valve springs usually increases the working stress to 55,000 pounds per square inch, an advance of practically 15 per cent. However, the deflection tests show that a stress of 55,000 pounds is not excessive, so that if it were ever necessary under unusual conditions to increase the

boiler pressure by 15 or 20 pounds, the springs could be set down the additional amount with perfect safety. Similar tests have been made on locomotive and straight-bore safety valves.

COAL.

Tests of coal have been made annually from storage in the open, dry storage and subaqueous storage under the same conditions. A 24-hour test with each variety is conducted on a B. & W. marine boiler under $\frac{3}{4}$-inch stack draft. To date, the results indicate no appreciable deterioration due to length of storage or any great advantage of one class of storage over another, except that the dry storage coal is more liable to form objectionable clinker and soot, the soot being due to the increased proportion of slack. The storage tests are continuing.

The raising of the old U. S. S. *Maine* afforded an unusual opportunity to examine coal which had been under water in Havana harbor for fourteen years. Although the colliery origin of the coal could not be determined absolutely, due to the destruction of original records, the character of the fuel was fixed approximately by the Bureau of Supplies and Accounts and the trial showed that, except for the sand and silt which had mixed with the coal during submersion and a slight increase in oxygen content, the evaporative power was unchanged.

The steaming section has recently undertaken a comparative test of Bering River (Alaska) coal with Pocahontas fuel from the naval stores at Bluefields, W. Va. The U. S. S. *Maryland* has made a service test on the Alaskan fuel, so that results are available under both testing plant and ship conditions. A very complete report of these tests together with geological data and analysis of the transportation problem has just been printed as a Government document.

METERS.

The need of accurate fluids meters can be appreciated by any engineer officer who has attempted to check leaks and losses in pipe lines.

The Station tests show that the displacement meters are uniformly bad. They indicate properly when new, but develop an increasing slip and error after being in service for a time. One meter with a good reputation—to judge from the builders' advertisement—wears so rapidly that the passage of 40,000 cubic feet made the instrument register inaccurately below 50 per cent. capacity, the error in some cases being 17 per cent. The exception to the general run of inaccurate meters is a fuel-oil meter in which the displacement element is backed up with springs which compensate for wear. Of course the conditions of operation are more favorable with oil than with water.

Some experimenting has been made with the Venturi meter, an instrument which registers difference in rate of flow between two unequal cross sections in the same pipe line by a difference in pressure. The pressure difference is so small, however, that it can only be indicated by the elevation of a mercury column. There are no moving parts and consequently no wear, but the improper manipulation of certain bypass valves will temporarily put the meter out of business by flushing the mercury in the water system. The accuracy of the meter is not effected by an angle of roll of 20 per cent. to the vertical.

PYROMETERS.

Recording thermometers and pyrometers have been tested in order to eliminate from naval use those which are too delicate for continuous duty. In calibrating these instruments a pendulum 16 feet long was slung from one of the roof trusses, and the test officer made the comparison between the pyrometers and the standardization temperatures while swinging thereon through the angle of roll of one of the battleships.

CONCLUSIONS.

It would be impossible to present all the important results obtained in five years of development, but the character of the work and the most important facts may be summarized in the following classification :

(*a*) Reduction in cost of standard articles whose consumption cannot be reduced.

(*b*) Reduction in consumption of standard articles by more economical use or application.

(*c*) Substitution of a cheaper but equally serviceable article for a given demand.

(*d*) Revelation of minor defects in an otherwise good design, and ultimate perfection of same by the Government or manufacturer.

(*e*) Elimination of material which on short stereotyped tests are satisfactory, but which fail in endurance competition.

(*f*) Trials to determine the most economical machine of a class.

(*g*) Elimination of faulty material and improvements in metallurgical processes.

(*h*) Providing design and specification data for the Department.

(*i*) Elimination of undesirable or freak designs and the protection of the Bureau of Steam Engineering against cranks.

The future work of the Station will largely depend upon the developments in propulsive and auxiliary machinery and upon the extent to which commanding and engineer officers make use of the facilities provided for the examination of defective material or investigation of deficient apparatus.

OPTICAL GLASS.

WITH SPECIAL REFERENCE TO ITS MANUFACTURE, OPTICAL FAULTS AND TESTS.

By Lieutenant F. J. Cleary, U. S. N.

Section I.

GLASS AND ITS MANUFACTURE (WITH SPECIAL REFERENCE TO OPTICAL GLASS).

"Glass" is a general term used to group together all bodies which have certain common well-defined characteristics. An exact definition of the term "glass" cannot well be made. While "glass" and "transparency" are usually considered as synonymous, there are bodies which are classed as true glasses which are not transparent and some which are not even translucent.

In general terms, all glasses are hard and brittle, but the degree of hardness and brittleness varies widely, and there are some metals and some minerals which are not only harder, but also more fragile than any glass.

The only common characteristic that all glass has is that its structure is not crystalline but amorphous.

As a general thing all solid bodies have a definite or crystalline structure, but this is not the case with vitreous bodies. Every property of glass is explicable only by assuming that it has the same molecular arrangement as a liquid. When a crystalline body passes from the liquid to the solid state, the transition takes place at one definite temperature, and is accompanied by a considerable evolution of heat which temporarily halts the solidifying process. With glass, on the other hand, the transition from the liquid to the solid state is so continuous and gradual, that the most delicate instruments have failed to record either evolution of heat or retardation of

the solidifying process; the solidifying process being simply a gradual stiffening without change of structure. All glass will, however, assume a crystalline structure if maintained too long at the critical point. This crystallization is known as devitrification, and the glass manufacturer must safeguard himself against it.

Glass in the liquid state is a mixture of certain chemicals in solution. The most common chemicals are the silicates and borates. Under ordinary conditions of cooling these chemical solutions will remain mutually dissolved. Each constituent, however, has its individual solidifying point, and if the molten glass is maintained slightly below one of the critical temperatures that particular constituent will begin to crystallize. In some cases devitrification can hardly be prevented; in others it is a matter of maintaining the glass for hours at the critical point. To prevent devitrification the glass must be cooled at a relatively rapid rate through the critical range of temperature.

This tendency to devitrification places a natural limit on the number of bodies that can be obtained in a vitreous state. While a number of substances can be obtained in the vitreous state, comparatively few are ordinarily used in glass making.

Ordinary glasses are manufactured from mixed silicates of a few bases, the bases being:

Sodium Potassium	Alkalies.
Calcium Magnesium Strontium Barium	Alkaline earths.
Iron oxide Aluminum oxide	Present only in small quantities.
Lead oxide.	

Optical glasses, of course, vary more widely in their constituents.

As previously stated, glasses are not definite chemical

compounds, they are mutual solutions of a number of definite chemical compounds.

In addition to the limit set by the tendency to devitrify, the range of glass composition is limited by two other considerations: one the excessive cost and scarcity of otherwise suitable elements such as thallium, etc.; the other, the excessive furnace temperatures required to fuse certain substances. Excessive proportions of silica, lime, etc., raise the fusing point. When this temperature exceeds about 1,600 degrees C., glass manufacture in ordinary furnaces is not possible. Pure silica produces a very excellent glass, but it cannot be fused in the ordinary regenerative gas furnaces used in glass manufacture. Small quantities of this glass can be produced in oxy-acetylene laboratory furnaces, and a poorer grade can be made in larger quantities in electric furnaces.

A limit is also set by the chemical behavior of the glass during manufacture and in use. Glass solutions tend toward a state of saturation and, while in a molten state, a glass rich in silica and deficient in bases will dissolve and absorb any basic material with which it comes in contact. Similarly a glass rich in bases and poor in silica or other acid constituents will absorb any acid body. Optical glasses are fused in fire-clay crucibles of such a chemical composition as to supply some of the constituents which the glasses need. Special note should be made that the dense lead and barium optical glasses, which are very rich in basic constituents, rapidly attack any fire clay.

The chemical composition of the finished glass is shown by the effect of moisture and carbonic acid in the atmosphere. Glasses which contain an excessive content of alkali, are found to be markedly hygroscopic and will suffer rapid decomposition, especially in a damp atmosphere. All glass is affected by pure water to a certain extent. In the best glass, the effect is inappreciable, the effect increasing with the proportion of alkali in the glass.

Within the limits discussed above the glass maker selects his raw material, having in view the intended use.

As a general thing, acids have very little, if any, effect upon good glasses. The action of phosphoric and hydrofluoric acid on glass is very marked. Hydrofluoric acid, both in the liquid and in the gaseous form, is very largely used in etching glass.

The effect of atmospheric agents on glass is so important that great endeavors have been made to develop a reliable test for this purpose, so that glass may be selected that will not be affected by atmospheric agents.

One of these tests consists of immersing strips of different glasses in an aqueous ether solution of iod-eosin, which forms a strongly adherent pink film on the less stable glasses. The depth of color of this film gives a measurement of the relative instability of the glasses; the best glasses remain practically free from color even after prolonged exposure. There are other stability tests, but great reliance cannot be placed upon any of them because, in some cases, the glasses shown to be least stable under the test are those glasses which have given great satisfaction in world-wide practical use.

The hardness of glass is of considerable importance, especially in the case of lenses of telescopes and other optical instruments aboard ship where the hardness is a direct measure of the resistance of the glass to scratching from frequent cleaning.

The most important characteristic of glass is its transparency. No glass is perfectly transparent. Aside from the fact that when light strikes a glass surface, no matter how perfectly polished, a part of it is reflected from the entering face and a part reflected from the emergent face; a certain percentage of light is also absorbed during its passage through the glass. In the best glass this absorption is very small if the glass is thin; but a piece of even the best glass several inches thick will show a noticeable absorption of light. The degree of absorption of light varies with the color of the light. When white light passes through glass the glass absorbs one of its constituent colors more than the others so that the emergent light has a slight color tint. The purest and whitest

glasses always show a distinct blue or green tint, if examined in thick pieces.

The question of light transmission will be taken up more in detail under "testing of optical instruments."

The purely optical qualities of glass, *i.e.*, light transmission, absorption, refraction, dispersion, etc., will be fully dealt with later.

RAW MATERIALS.

As the transparency of glass renders plainly visible in the finished product any defects of color or quality, the raw materials used in the manufacture of optical glass must be practically free from all impurities. While the volatile and combustible substances are usually completely eliminated during the melting, all fixed substances forming part of the charge will appear in the finished glass. The selection of the raw materials is thus a vital matter.

In addition to freedom from impurities, raw materials for optical glass must be uniform in composition.

The raw materials ordinarily used are:

Material containing silica,

Material containing alkalies,

Material containing bases other than alkalies.

SILICA MATERIAL.

The principal silica material is sand. For optical glass a very pure sand is required, containing less than .05 per cent. iron and not more than .05 per cent. of other impurities, such as alkali, lime or alumina.

Silica is obtained in other forms than sand, noticeably in sandstone.

Silica obtained in the form of crushed stone is not as satisfactory as sand. It is not as pure, nor as homogeneous, and it has to be washed to remove the dust, resulting in loss of material. The same objections are found in the use of quartz or flint, with the added objection of the great difficulty of crushing these exceedingly hard materials. At one time

ground flint was very largely used in making optical glass, and the name "flint" is in common use, although the term now denotes a glass having a large proportion of lead and being necessarily a heavy, dense glass of high refractive power.

ALKALI MATERIAL.

Alkalies are obtained in the original forms of potassium chloride and sodium chloride.

From a manufacturing standpoint, it is not possible to use the chlorides because they are volatile at glass melting temperatures and they are acted upon by hot silica only in the presence of water vapor. Consequently, chlorides would be vaporized before they could combine with the other ingredients.

The alkalies are used in the form of sulphate of soda (salt cake) and, less commonly, carbonate of soda (soda ash).

BASIC MATERIAL OTHER THAN ALKALIES.

The more important of the other bases are calcium oxide (lime) and lead oxide. The usual form of calcium oxide used is either the carbonate or the hydrate (slacked lime).

Lead oxide (generally in the form of red lead) is extensively used in the manufacture of "flint" optical glass.

Barium oxide, magnesia, and a small number of other substances are also used in optical glass.

Zinc oxide is used in a special "zinc crown" for certain optical purposes.

FURNACES AND CRUCIBLES.

Furnaces employed in glass making are of two general types,—tank furnaces and crucible or pot furnaces.

Tank furnaces are used for the production of great quantities of glass, such as rolled plate glass, sheet glass, etc.

Tank furnaces are not suited to the production of optical glass.

In the manufacture of optical glass pot furnaces are exclusively used for the reason that the composition of the glass

can be accurately regulated; that the molten glass can be better protected from contamination by the action of the furnace gases, or by the material forming the furnace roof dropping into the glass; and that it is possible to fuse in pots materials that could not be kept together in the open-tank furnace long enough to combine.

Pot furnaces are gas furnaces of either the "regenerative" or the "recuperative" type. These furnaces so closely resemble in principle and construction the furnaces used in steel making that no description is necessary.

Furnace linings and crucibles are made of some form of fire clay. In selecting refractory materials for pot furnaces and crucibles two distinct considerations must be borne in mind.

The material used for lining the furnaces must be able to resist the disintegrating action of the heated furnace gases for long periods of time. This material need not be proof against the dissolving action of the glass, as it never comes in contact with it.

On the other hand, the material for making crucibles must first be proof to a great extent against the dissolving action of the glass itself, and must be capable also of resisting the action of the furnace gases without fusion or even serious softening; the demands in this particular are not so exacting as in the case of the furnace lining, as a crucible for optical glass is used but once. In addition, the material used must be of sufficient strength when dried to permit transportation when filled.

All fire clays are more or less affected by the dissolving action of the molten glass. The manner in which the clay dissolves is of more importance than the rate. A clay that dissolves rapidly but uniformly is preferable to a clay that, while it dissolves slowly does so irregularly, as in this case lumps of undissolved fire clay will be found in the finished glass in the form of opaque enclosures called "stones." Especial care must be taken that the fire clay chosen is free from iron or any other materials that would introduce impurities into the glass. The best results are obtained by using a clay especially adapted to the glass materials to be melted.

Crucibles for optical glass usually vary between 30 and 50 inches in diameter and are of the covered type, of the general form shown by the accompanying figure.

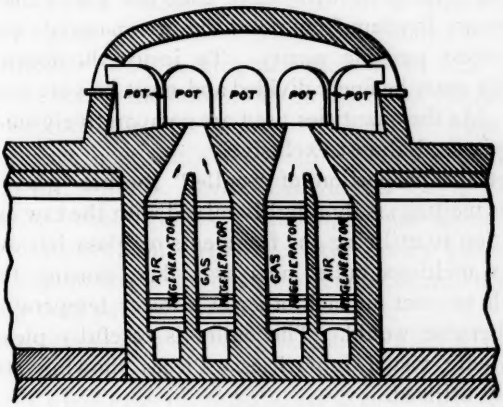


FIG. 1
SECTIONAL DIAGRAM OF A REGENERATIVE POT FURNACE WITH COVERED POTS

The furnaces for optical glass are made to take one pot only instead of ten or twelve pots, as shown in Fig. 1. The reason for this is that while in ordinary glass manufacture the raw materials can be chosen to suit furnace conditions, and to facilitate melting, and "fining" (the process of freeing the molten mass from gas bubbles); in optical glass manufacture these methods making toward technically perfect glass cannot be used at the very time when they would be most desirable, because the raw materials for optical glass must be chosen for the chemical composition that will give the desired optical

FIG. 2
COVERED POT FOR MELTING OPTICAL GLASS

properties. Consequently, the furnace conditions must be adapted to the optical glass materials. The heat, both as to degree and duration, must be adapted to each pot. This would be impossible with more than one pot in the furnace.

To secure freedom from color the raw materials must be of the greatest possible purity. To insure homogeneity the materials must be finely divided and must be very thoroughly mixed. As the quantities used are comparatively small, hand mixing is used almost exclusively.

A certain proportion of "cullet" (broken glass from a previous melting) is thoroughly mixed with the raw materials. In addition to utilizing the fragments of glass left over from previous meltings cullet acts as a flux, causing the other materials to react on each other at a lower temperature than they otherwise would. The cullet is carefully picked over to eliminate visual impurities. Pieces showing striae are generally utilized.

The empty pot is placed in a kiln and gradually brought to a red heat, this preliminary heating taking four or five days. When properly heated the pot is removed from the kiln and transferred as rapidly as possible to the melting furnace which has been brought up to the same temperature. This is necessary to prevent shrinkage and breakage of the pot, which would result if it were placed in a furnace at melting heat. The opening to the melting furnace is carefully sealed by temporary brick work, an opening in the temporary work, closed by fire-clay slabs, being left opposite the mouth of the pot. The furnace is then brought to the melting heat.

A quantity of "cullet" is put into the pot and permitted to melt, forming a coating of molten glass on the bottom and on the lower part of the walls of the pot to protect it from the violent attacking action of the melting raw materials. The first charge of raw materials is now placed in the pot. As the materials froth up during melting, care must be used in charging to prevent overflow. Raw material occupies more

space than the molten mixture, so that as soon as the first charge is in a molten state a second charge is introduced.

These charges become smaller and smaller until the pot is filled with molten material, which is full of bubbles of all sizes. The glass is "fined" or freed from bubbles by increasing the furnace heat, making the glass more fluid and increasing the size of the bubbles by expansion of the contained gas, the bubbles rising to the top. The molten mass is kept at this extreme heat until free from bubbles, sometimes for as long as thirty hours. In the case of the lead glasses and other easily fusible glasses, this temperature is maintained without difficulty; but with the hard crown glasses it is difficult to maintain a high fining temperature without endangering both pot and furnace.

In some of the new and very valuable optical glasses it is impossible to secure entire freedom from bubbles, due to the fact that in some cases the bubbles are so small that they show no disposition to rise to the top, even when the glass is very fluid; in other cases there is a constant evolution of minute bubbles at the fining temperature. As these bubbles are very small the only optical drawback is that they prevent the transmission of the very small percentage of light that falls upon them. This defect is more than compensated for by the other optical advantages of these new glasses.

During the fining process the glass is examined from time to time for freedom from bubbles, by taking small samples or test pieces (called "proofs") out of the pot. The presence of even minute bubbles in these proofs is readily detected.

When the glass is free from bubbles the furnace heat is decreased to a certain extent.

As the greater part of the impurities are lighter than the molten mass, they will float to the top and the surface is skimmed to remove these impurities.

To secure homogeneity and to prevent striae the molten glass is then thoroughly stirred by a cylinder of thoroughly-burned fire clay heated to a red heat. The stirring is continued during the gradual cooling of the mass until it is so

stiff that the stirrer cannot be moved. The duration of the stirring varies from four to twenty hours, depending upon the glass and upon the size of the pot. The stirrer is left in the cooled mass.

To prevent devitrification it is necessary as soon as stirring ceases to cool the glass as rapidly as is consistent with safety down to a temperature where it becomes "set." After it has reached this point, any farther rapid cooling would result in cracking and fragmentation of the mass; and, accordingly, it is necessary to slowly cool (anneal) the glass down to ordinary temperatures.

The "setting" and "annealing" are secured as follows: As soon as stirring ceases the pot is withdrawn from the furnace and allowed to cool to about the annealing temperature. It is then placed in an annealing kiln at a temperature of about 400 degrees C. to 500 degrees C. and slowly cooled to ordinary temperatures. Annealing takes from one to two weeks, according to the size of the melting. When cooled, the pot is withdrawn from the annealing kiln and the pot broken away from the glass.

Under specially favorable conditions, the whole melting may be one intact mass weighing perhaps as much as 1,200 pounds. Generally, however, the mass will be found cracked into a few large lumps and a great number of smaller fragments. These various-sized lumps are carefully inspected, and any visible imperfections removed by the chipping hammer.

The lumps of glass are then heated to a red heat, and placed in red-hot fire-clay molds, suited to the size of the lump. With glass intended for special purposes to prevent strain the glass is not forced, but settles into the molds by its own weight. The final annealing follows, in which the glass is cooled down to ordinary temperatures. The duration of this annealing depends upon the size of the lump and the purpose for which intended.

Ordinarily, the annealing is done in a large kiln and takes from six to eight days.

For special purposes, such as polariscopes, saccharimeters,

microscopes for petrographic work and very large telescopes, where perfect freedom from double refraction is necessary, special annealing kilns are used, where regulation of the fall of the temperature can be carried out with extreme accuracy. Annealing kilns are in use where the rate of cooling is so small and gradual that a fall of 1 degree C. takes several hours. In such kilns, even large blocks of glass may be perfectly annealed.

When the various blocks of glass are removed from the annealing kiln, two of the opposite edges are ground parallel and polished. They can then be examined for bubbles, strains, striae and other defects. This examination results in the rejection of a considerable number of the blocks.

The melting is considered very satisfactory if the yield of perfect optical glass amounts to from ten to twenty per cent. of the entire contents of the pot. While it is of frequent occurrence that 100 pounds of good optical glass is obtained from a pot in various sized blocks, it is rarely that a perfect block of 100 pounds weight will be obtained.

COMPOSITION OF SOME SPECIMENS OF JENA GLASS.

Light Phosphate Crown.

	P_2O_5	70.5
O 225	K_2O	12
$\mu_D = 1.5160$	Al_2O_3	10
$\nu = 70.3$	MgO, B_2O_3, As_2O_5	7.5

Boro-silicate Crown.

	SiO_2	68.24
	B_2O_3	10.00
O 627	K_2O	9.50
$\mu_D = 1.5128$	Na_2O	10.00
$\nu = 63.7$	ZnO	2.00
	Mn_2O_3	0.07
	As_2O_5	0.20

Heavy Barium-silicate Crown.

O 211	SiO_2	48.7
$\mu_D = 1.5727$	BaO	29.0
$\nu = 58$	ZnO	10.3
	Alkalies & B_2O_3	12.0

Light Boro-silicate Flint.

O 658	SiO_2	32.7
$\mu_D = 1.5452$	B_2O_3	31.0
$\nu = 50.3$	PbO	25.0
	Alkalies & Al_2O_3	11.3

Light Silicate Flint.

	SiO_2	54.22
	B_2O_3	1.50
O 154	PbO	33.00
$\mu_D = 1.5710$	K_2O	8.00
$\nu = 43.1$	Na_2O	3.00
	Mn_2O_3	0.08
	As_2O_5	0.20

Heavy Silicate Flint.

	SiO_2	28.36
O 165	PbO	69.0
$\mu_D = 1.7545$	K_2O	2.50
$\nu = 27.6$	Mn_2O_3	0.04
	As_2O_5	0.10

Densest Silicate Flint.

S 57	SiO_2	18
$\mu_D = 1.9625$	PbO	82
$\nu = 19.7$		

SECTION II.

PROPERTIES OF OPTICAL GLASS.

The characteristics affecting the value of optical glass may be divided into two groups: one, the purely optical properties which directly influence the light in passing through the glass; the other, general features of special importance in optical glass.

OPTICAL PROPERTIES.

The purely optical properties may be listed as follows: homogeneity, transparency, freedom from color, refraction, dispersion.

The most important of these is homogeneity.

If a thick piece of ordinary glass is examined, the layers of different densities will show clearly in the form of internal irregularities. These faults are known as veins or striae. It can be stated that only a small proportion of the glass in a pot is quite free from striae. Many times the striae are so slight that they would not be detected ordinarily until the lens was ground and polished. They would then become plainly evident in affecting the sharp definition of the image formed by the lens, and the lens would have to be rejected.

To prevent loss of time and labor in useless grinding and polishing the glass blocks are tested for striae in a way that detects the smallest striae. The method is shown diagrammatically in the accompanying figure 3.

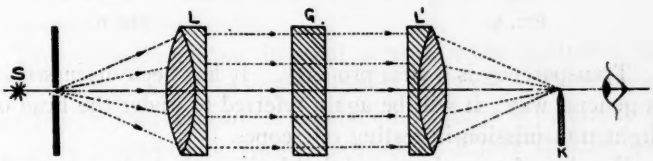


FIG. 3.

A source of light "S" is placed behind a screen located in the focal plane of the lens "L." The light passes through a hole in the screen situated on the optical axis of the lenses. The parallel-sided block of glass is placed at "G", between the two lenses. A knife edge is placed at "K" so as to hide the source of light from the eye, located at "E." If the plate is free from striae the light which falls upon it parallel will emerge parallel and the whole field will appear uniformly dark. If there is striae present the striae will appear as bright lines on the dark field.

FIG. 4.

A lens may be tested in a somewhat similar way. As shown below, the source of light "S" is located at a considerable distance from the lens, a knife edge "K" is employed as before to hide the source of light. If the lens is free from striae the field will appear dark (Fig. 5). Striae will show as bright lines (Fig. 6).

FIG. 5.

FIG. 6.

Transparency is a vital property. It has been discussed in a general way; it will be again referred to under the head of light transmission in testing telescopes.

Freedom from color is advisable in optical glass, but it is not as essential as some of the other optical requirements.

Refraction and dispersion will be discussed in detail later.

GENERAL FEATURES.

The general features of special importance in optical glass may be listed as follows: chemical stability, mechanical hardness, freedom from internal strains.

Chemical stability is a very essential feature, for the best lenses would soon be useless if they were easily affected by the action of atmospheric moisture. "Hard crown" and "boro silicate crown" are very durable and chemically resist-

ant; but in other cases, where the extreme optical properties demanded have been secured by a change in the chemical composition, chemical stability has been sacrificed. A limit is soon reached where the serious disadvantage of chemical instability outweighs the optical properties gained. Lenses made from unstable glass may be protected by cementing them between two components of stable glass, but this is rarely done, as it imposes limitations on the optical design.

Improper handling and cleaning greatly shortens the life of a lens. A glass surface is seriously affected by the film of organic matter left upon it when it is touched by the fingers. If the glass is not of the very best quality these finger marks develop into iridescent spots which frequently become black stains. Dust particles will have a similar effect.

Mechanical hardness is an important feature. In general, a high degree of hardness is accompanied by a low refractive index. This is undoubtedly true when there is a considerable difference of hardness, as in comparing a hard crown and a dense flint. Where the difference of density or the difference of the refractive indices is small, the lighter glass will not necessarily be the harder.

Entire freedom from internal strains, while desirable, is not essential except for special optical purposes. Experience teaches the manufacturer what amount of strain is permissible in glass intended for various purposes. Entire freedom or comparative freedom from strains depends upon the annealing. Internal strains are readily recognized by the polariscope. A perfectly annealed glass, entirely free from internal strains, produces no effect upon a beam of polarized light traversing it, while even slightly strained glass will show a marked double refraction. A serious amount of double refraction indicates a state of strain which may easily lead to fracture of the whole piece, either in the earlier stages of grinding or if subjected to any shock at any time, even when finished.

Two methods of examining for strain are given here.

A powerful source of light is placed behind a screen at "S," the opening in the screen being on the optical axis and

in the focal plane of the lens "L." "N" is a Nicol prism; the second Nicol prism at "N'" is rotated until they are crossed, completely suppressing the light so that the field viewed by the eye at "E" is quite dark. The glass plate "G" to be tested is placed anywhere between the Nicol prisms. The slightest strain in the plate will depolarize some of the light and light will appear in the field. This method of

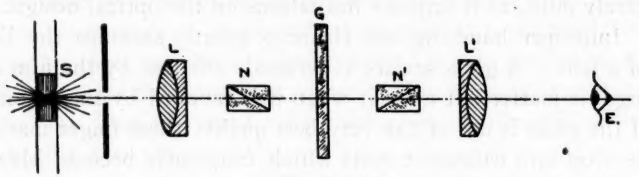


FIG. 7.

testing, while very sensitive, has the disadvantges that the sides of the glass plate "G" must be parallel and the lenses "L" and "L'" must themselves be free from strain.

A more practical and more satisfactory method of testing is illustrated by Fig. 8.

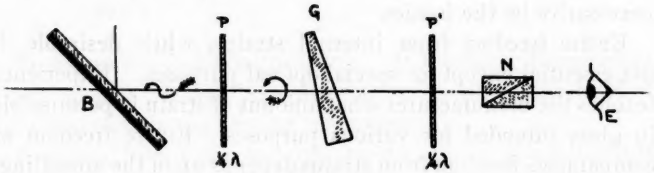


FIG. 8.

A plate of glass, black-coated on the under side, causes plane polarization of the reflected light, which is transformed into circular polarized light by the ¼-wave length plate at "P." A second ¼-wave length plate at "P'" again transforms the light into plane polarized light. Between the plates "P" and "P'" is inserted the plate "G," or the lens or prism, which it is desired to test. If free from strain it will appear to be of a neutral tint. Any strain will show as color bands, the brilliancy and width of the bands increasing with the amount of strain. This method

has the great advantages that glass of any shape may be tested, and a plate of glass may be compared with another plate which is under a known amount of strain.

SECTION III.

OPTICAL FAULTS AND TESTS.

This section will be divided into two parts.

PART 1. The principal faults of single lenses and prisms, with the way in which they manifest themselves and their remedy.

PART 2. The faults and properties of optical systems as a whole, with the methods of testing telescopes to determine the faults and to measure the optical properties.

PART I.—DEFECTS OF SINGLE LENSES.

This table is taken in great part from Silvanus Thompson's "Optical Tables and Data."

Faults.	*Manifestation.*	*Remedy.*
Due to material.		
Chromatic aberration.		
(a) of focal plane (b) of magnification.	Color fringes on edges of images and of visible field.	Use of achromatic lens of two kinds of glass. Can be partially remedied by stopping down.
Secondary spectrum.	Faint color tinge of minute bright objects.	Unimportant, usually uncorrected.
Streakiness	Streaks in glass. Images of bright points confused.	Reject, bad glass.
Double refraction...	Images doubled.....	Reject, poor annealing.
Due to form.		
Cylindricity	Vertical and horizontal lines not in focus at the same time.	Reject, lens has astigmatism, badly ground.

Faults.	*Manifestation.*	*Remedy.*
Spherical aberration.		
(a) Central.....	Images of bright points blurred even at center of field.	Partial remedy, stop down. Badly calculated lens curvature. Lenses may be retouched to correct error or better calculated lenses may be substituted.
(b) Coma.....	Images of points not at center of field blurred into pear shape.	
(c) Radial astigmatism.	Images of points not at center distorted into two focal lines at different distances from lens.	
Curvature of focal plane.	Images at center and at edges of field are in focus at different distances.	Use different lens combination.
Distortion of image in its plane.	Barrel distortion or pincushion distortion of image.	Lens combination badly designed. Try shifting stop.
Due to bad mounting.		
Obliquity of mounting.	Vertical and horizontal lines not in focus at the same time.	Set straight in mounting.
Decentering.....	Image shifted out of direct line.	Lens badly ground or mounted. Regrind or remount so that thickest part is in center.
Due to stray reflection.		
Flare spot	Flare intruding in middle of field.	Lens combination not well adjusted. Alter distance between lenses.

The faults of prisms are—

Faces not accurately ground; so that the angle between them is not within the tolerance demanded.

Faces not ground and polished perfectly plane.

Unsuitable glass.

The tolerance of accuracy of the angle between prism faces depends upon the use to which the prism is to be put.

In range-finder work the tolerance of accuracy of the angle varies from $\pm 3''$ to $\pm 6''$ of arc.

In Brashear-Hastings erecting prisms the tolerance of accuracy of the roof angle must be $\pm$ 20″ of arc.

In Porro prisms the tolerance of accuracy is $\pm$ 5′. The angles are measured by the spectrometer.

The prism faces should be plane within very small limits. A slight cylindrical surface will result in astigmatism of the optical system as a whole.

The accuracy of the prism faces is tested by the use of a test plate showing Newton's color bands. The direction of the color bands will show the direction of the axis of curvature while the width of the bands will show the variation of the surface from a true plane. This subject is dealt with more fully under the head of Newton's rings.

The glass used should be of the best quality, practically free from bubbles and free from color; the light transmission should be high. Borosilicate crown glass is usually used. Barium silicate crown and baryta light flint also give excellent results.

NEWTON'S RINGS.

If a convex and a concave lens of slightly different curvature are so placed that their centers are in contact, there will be a thin film of air between them. Near the point of contact the thickness of this air film will be very small when compared with the wave length of the light. The point of contact will be surrounded by a black circular spot if viewed by transmitted light or by a bright spot if viewed by reflected light.

The thickness of the air film increases from the contact point to the edges of the lenses. As the surfaces of the lenses are spherical, the thickness of the air film will be uniform at all points on the circumference of a circle whose center is the point of contact.

If the lenses are illuminated by monochromatic light and they are viewed by reflected light, the central black spot will be surrounded by concentric bright and dark circles; if they are viewed by transmitted light the bright and dark circles are interchanged. If the lenses are viewd by white light instead of monochromatic light the rings will be colored.

In testing lenses for accuracy of grinding and polishing, a test lens having the desired curvature is used. The test lens is placed in contact with the lens to be tested, care being taken that both surfaces are perfectly clean and dry, and the lenses squeezed together. If the lens is perfect the air film between them will be of uniform thickness and color will be uniform all over the surface. Irregular bands or patches of color show that the surface is not accurate and point out clearly the parts of the lens needing attention. This method is very similar to the method of testing a plane metal surface by means of a surface plate.

The method of testing a single convergent lens, such as an objective, for chromatic and spherical aberration is given here (Fig. 9).

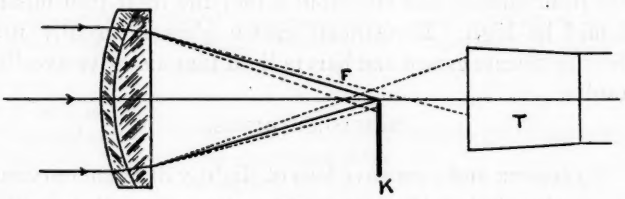


FIG. 9.

Light from any distant object, falling upon the lens, will be brought to a focus at F by the lens to be tested. The telescope T is sharply focused on the lens surface. A knife edge is placed at K in such a way that the image is completely hidden. If all the rays come to a focus at F, the lens will be aplanatic and will appear perfectly dark (Fig. 5).

FIG. 10.

FIG. 11.

If there is spherical aberration some of the rays will focus inside and outside of the point F as shown by the dotted lines in Fig. 9, and part of them will reach the telescope, making the lens surface partly light and partly dark (Figs. 10 and 11).

Fig. 11 shows an especially bad case of spherical aberration.

If there is chromatic aberration the lens will appear colored, the colors changing if the knife edge K is slightly moved.

PART II.—FAULTS AND PROPERTIES OF OPTICAL SYSTEMS.

The faults of optical systems are—chromatic aberration, spherical aberration, coma, astigmatism, curvature of field, distortion.

The properties of optical systems are—aperture of objective lens, exit pupil, eye distance, magnifying power, field of the telescope, field of the eyepiece, definition, resolving power, light transmission.

Optical systems should be tested for all of the above points and, in addition, for parallax of the cross lines, for collimation, and for cross-line illumination, if provided.

TESTS.

All lenses and prisms must be perfectly clean.

Chromatic Aberration.—A white disc should be used, situated at such a distance that the telescope may be sharply focused upon it.

Adjust the eyepiece draw tube (or the objective lens) until the disc is in sharp focus. The disc should then be free from color. Slowly move the draw tube in and out. If, when the draw tube is moved in, a light yellow fringe is seen around the edge of the disc, which changes to purple when the draw tube is moved out, the telescope is well corrected for primary chromatic aberration (red and blue).

Spherical Aberration is an aberration of the rays of light parallel to the axis. Cover the objective lens by a ring of black paper, reducing the diameter of the aperture by one half and leaving the center of the objective lens clear.

Sharply focus the telescope on a distant object, on the cross-line intersection. Mark the position of the telescope draw tube. Now remove the paper ring and cover the center of the objective lens (previously left clear), and sharply focus the telescope on the distant object on the cross-line intersection ard mark the new position of the draw tube. If practically free from spherical aberration, very little refocusing will be required; the amount of movement of the draw tube will be a measure of the amount of spherical aberration.

Coma is spherical aberration of the rays of light oblique to the axis. Sharply focus the telescope on a small, round, white object near the edge of the field, and observe whether any flare extends from the image; the entire outer zone of the field should be examined in this way.

Astigmatism is due to the curvature of a lens surface being different for planes through the optical axes which are inclined to each other. It may be caused by faulty original grinding of lenses, or by the lens being under strain by setting up too hard on a locking ring, or by change of form of the lens due to age. It is also caused by prism surfaces not being ground truly plane. It is readily recognized by parallax of one cross line when parallax is eliminated in the other cross line. In old telescopes the fault generally lies in the objective lens, but each element of the optical system may have to be examined. The remedy lies in regrinding and repolishing the lens or prism at fault.

Curvature of Field cannot be completely overcome because the image, being due to a curved surface, will naturally be curved; the shorter the focal length of the objective lens the more will the field be curved. Whether the curvature of field is so great as to be prohibitive can be determined by first sharply focusing the telescope on a point in the center of the field and then noting whether points at the edge of the field are clear and well defined. If the edges of the field are hazy, move the draw tube in or out until the edges of the field are sharp and distinct; the amount of movement of the draw tube is a numerical measure of the curvature of the field.

Distortion is caused by the different magnification of different parts of the image.

Draw horizontal and vertical parallel lines on a square piece of flat cardboard. Place the cardboard in such a position that it nearly fills the field of the telescope. When viewed through the telescope, if the cardboard presents the appearance of Fig. 12 the telescope is free from distortion. If there is distortion present, a virtual image will have the appearance of Fig. 13; a real image will have the appearance of Fig. 14.

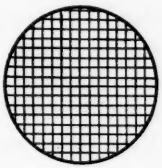


FIG. 12.

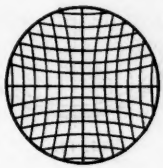


FIG. 13.

FIG. 14.

PROPERTIES OF OPTICAL SYSTEMS AND METHODS OF MEASURING THEM.

Aperture of objective lens, exit pupil, eye distance, magnifying power, field of the telescope, and field of the eyepiece, have been clearly defined and carefully explained. Their numerical values are obtained as follows:

Aperture of the objective lens. Place the eye about ten or twelve inches from the eye lens so that the exit pupil is seen.

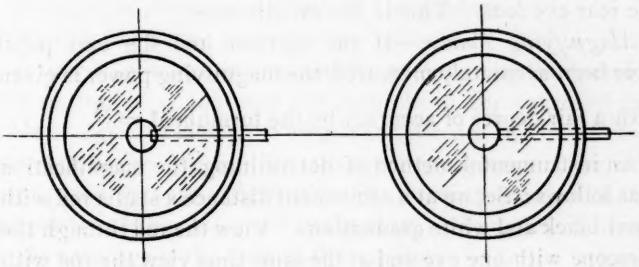


FIG. 15.

FIG. 16.

Hold a scale in front of the objective so that it can be seen through the exit pupil (Fig. 15). Draw the scale back until the edge just disappears (Fig. 16). The scale will now occupy the position in Fig. 17.

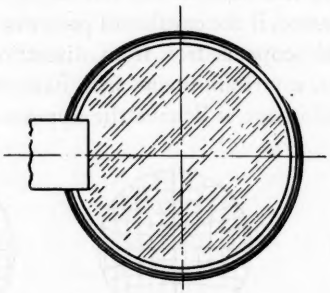


FIG. 17.

The distance from the edge of the scale to a corresponding point on the opposite side will give the free aperture; in this case, two inches.

Exit Pupil.—Direct the telescope toward the clear sky and place a scale in rear of the eyepiece; move the scale away from or toward the eyepiece until the edges of the exit pupil are sharply defined. The size of the exit pupil can be easily measured on the scale.

Eye Distance.—When the position of the exit pupil has been determined as in the paragraph above, measure the distance from the sharply-defined exit pupil to the rear face of the rear eye lens. This is the eye distance.

Magnifying Power.—If the aperture and the exit pupil have been accurately measured, the magnifying power is given with a fair degree of accuracy by the formula $M = \frac{A}{e}$.

An instrumental method of determining the magnification is as follows: Set up at a convenient distance a stadia rod with equal black and white graduations. View the rod through the telescope with one eye and at the same time view the rod with

the other eye unaided. The number of spaces seen by the unaided eye which are equalled by one space seen through the telescope will give the magnifying power of the telescope.

A more accurate means of measuring the magnifying power is by mounting the telescope in the center of the gaduated horizontal circle. Pick out any clearly defined horizontal object and move the telescope in azimuth until the vertical cross line is at one extremity of the object selected, read the horizontal circle. Rotate the telescope until the vertical cross line is at the other extremity of the object, read the horizontal circle; call the difference in readings D′.

Replace the telescope by a telescope having a known magnifying power M. Measure with this telescope the angular distance between the extremities of the object. Call this difference D.

We then have the ratio $\frac{M'}{M} = \frac{D'}{D}$, and $M' = \frac{MD'}{D}$, which gives the magnifying power of the telescope.

Field of the Telescope.—Set the telescope up close to and in the same horizontal plane as a theodolite, or any instrument provided with a horizontal graduated circle. Mark the two points on any convenient object at the extremities of the horizontal cross line of the telescope. Rotate the theodolite until the vertical wire covers one of the points, read the circle. Swing the theodolite until the vertical wire cuts the other point, read the circle—the difference between the two readings will be the field of the telescope.

Field of the Eyepiece is given by the product.

Magnifying power × field of the telescope.

It may be obtained instrumentally by removing the eyepiece and setting it so that the eye point is in the center of the table of a spectrometer. Swing the telescope of the spectrometer until the vertical line is tangent to one edge of the exit pupil, read the circle, determine the angular position of the other edge of the exit pupil in the same way. The difference of the readings is the field of the eyepiece.

Definition means the clearness with which an object is seen. If a telescope is said to have good definition it indicates that when in focus everything viewed through the telescope has a clear, sharp outline, while a telescope with poor definition makes objects appear blurred and indistinct.

As a result of numerous experiments, it has been shown that good definition is an important essential in a telescope, especially if intended for night use as well as day use. It can be easily shown that if two telescopes are set at the same magnifying power and are both pointed at the same object at night, the one having the better definition gives an image that is much easier to see and one that could be picked up much more readily. Another advantage is that when the definition is good, the object viewed appears larger than it does when the definition is poor, and an 8 magnifying power glass with good definition appears to give as much magnification as a 10 or 12 magnifying power telescope having poor definition.

To test for definition, use small, clear print at a distance of about fifty feet; sharply focus the telescope on the print, which should appear clear and well defined. Divide the distance of the print from the telescope by the magnifying power of the telescope and view the print from this new distance with the unaided eye. The distinctness of the print through the telescope at the greater distance should be about equal to its distinctness by the unaided eye at the lesser distance.

It the print is dull and indistinct and the finer details illegible, the definition is poor.

A more accurate test for definition is by means of an artificial star. If we place a glass globe in such a position that the sunlight or an artificial light is reflected to our eyes, and sharply focus the telescope on the globe, the reflected light will appear on the globe as a bright point of light (Fig. 18)

Move the telescope draw tube slowly in and out; if the definition is excellent, a series of concentric rings will appear around the bright point (Fig. 19).

If the definition is not excellent these rings will be dis-

FIG. 18.

FIG. 19.

torted, the distortion varying with lack of definition. This is a very exacting test, and a telescope that will stand it is an excellent instrument.

Resolving Power is the ability of a telescope to measure small angles.

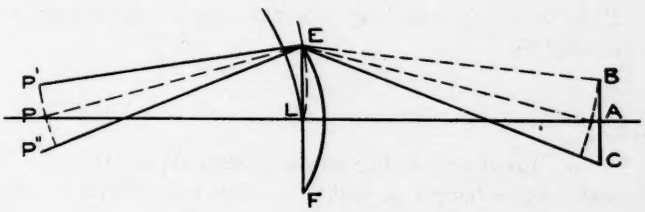


FIG. 20.

Fig. 20 shows a lens with two luminous points P′ and P″ equidistant from the axis. If waves of light from P′ and P″ are to be separately refracted by the lens, they must reach the lens surface distinct from each other, otherwise they will be refracted through together and will form one image instead of two.

If the waves from P′ and P″ coincide with each other at the point L on the axis; to form separate images at E they must be half a wave length apart at E, or $P''E - P'E = \frac{\lambda}{2}$.

Let $LP = u$, $AL = v$, $EL = r$, $P'P'' = \delta'$, $CB = \delta$, then these formula can be deduced

$$\frac{\lambda}{2\delta} = \frac{r}{v} \qquad \delta = \frac{v\lambda}{2r};$$

$$\frac{\lambda}{2\delta'} = \frac{r}{u} \qquad \delta' = \frac{u\lambda}{2r}.$$

The magnification of the object by the lens =

$$\frac{CB}{P'P''} = \frac{\delta}{\delta'} = \frac{v}{u};$$

$$\delta = \frac{v}{u} \times \delta' = \frac{v}{u} \times \frac{u\lambda}{2r} = \frac{v\lambda}{2r}.$$

When the above condition is fulfilled, the edges of the images will touch and they will be just distinguishable.

The theoretical resolving power of any telescope system is expressed by

$$\delta = \frac{a\lambda}{r};$$

where

δ (or sin δ) is the resolving power in seconds of arc.

λ = the wave length of light in millimeters (about .00056 millimeters).

r = the radius of the objective lens in millimeters.

a = a constant which is 0.61 for stars.

This value of a may without serious error be used for fine lines.

If we take a binocular with an objective aperture of 30 millimeters and a magnification of 6 diameters we have

$$\delta = \frac{.61 \times .00056}{15} = .000023 \text{ radians} = 4.7'';$$

this is the theoretical limit of resolving power independent of any magnification.

With a magnification of 6 diameters the theoretical limit

of resolving power would be apparently magnified and the theoretical *apparent* resolving power is $6 \times 4.7'' = 28''$ but as this is too small to be seen by the unaided eye, which has a limit of about $1'$, it is advisable to use an auxiliary telescope of a magnification of four or five, so that the lines used will appear to be separated by two or three minutes of arc.

A number of scales should be graduated in varying seconds of arc from a fixed distance; and the binocular placed at this distance; the auxiliary telescope should be sharply focused on a distant object and placed against the eye lens of the binocular, the scales should then be brought into sharp focus by focusing the binocular eyepiece. The smallest scale that can be read determines the resolving power of the binocular in seconds of arc.

The magnification of the binocular or the auxiliary telescope will have no effect if the resolving power of the optics of the binoculars is not good. For instance, if two lines are selected so that the distance between them subtends an angle of $5''$ of arc at the testing point, the binocular will not resolve them into two separate lines, no matter what the magnification, at this value is too close to the theoretical limit. Two lines subtending an angle of $20''$ of arc at the testing point can be resolved by the binocular, and the auxiliary magnification then becomes necessary to bring the angular difference between the two lines above the limit of the eye itself.

It is not feasible in optical instruments to equal the theoretical resolving power of $4.7''$ of arc multiplied by the magnification, but a theoretical resolving power of $1'$ of arc should be attained in any high-grade optical instrument.

This value of $1'$ of arc divided by the magnification of the instrument being tested will give the true resolving power which the instrument should have; in the case of 6 diameters magnification, this would be $10''$ of arc.

Light Transmission.—It has been previously pointed out that for efficient night use a sufficiently large exit pupil is the most vital single feature of design. Light transmission is a

very important essential and is affected by many features of design, these features being—quality of the glass (good or bad); type of glass (crown, flint, etc.); total thickness of the glass; polish of the refracting surfaces; condition of the balsam used in cementing the lenses.

In prism telescopes the following additional features are of importance: the silvering of the prisms; the type of prisms used.

A certain percentage of the light is lost at each refracting surface. This loss is given by the formula

$$R = \left(\frac{\mu - 1}{\mu + 1}\right)^2.$$

In the case of crown glass used for prisms where $(\mu) = 1.525$, $R = 4.3$ per cent.

For the purpose of approximate calculation, the amount of light lost by each two lens or prism surfaces can be taken as 9 per cent. of the light that strikes that lens or prism. This is a reason for cementing the two components of a lens together instead of leaving an air space between them.

The total theoretical amount of light transmitted through a telescope is given by the formula,

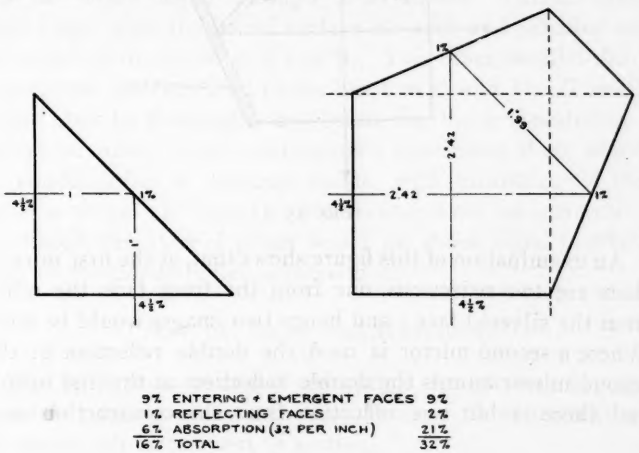
$$T = (1 - R)^s,$$

where S is the number of refracting surfaces.

This theoretical transmission is reduced by the amount of light lost by passing through the glass, which can be taken as about 3 per cent. per inch; and the loss at each reflecting surface.

It has been pointed out that in the case of total reflection at a 90-degree prism surface, less than 1 per cent. of light is lost. When, however, the reflecting surface of such a prism is silvered, the silver absorbs part of the light. The amount of light absorbed depends upon the perfection of the silvering; but even where the silvering is excellent the loss of light is

from 3 per cent. to 5 per cent. This increase in loss of light is regrettable but unavoidable. Silvering the reflecting faces of prisms is a necessity, as any dirt or moisture on the reflecting face of the prism causes a loss of light and of definition that would be fatal for night efficiency.



9%	ENTERING + EMERGENT FACES	9%	
1%	REFLECTING FACES	2%	
6%	ABSORPTION (3% PER INCH)	21%	
16%	TOTAL	32%	

FIG. 22.

Fig. 22 shows the disadvantage of using pentaprisms in telescope construction. Using a theoretical loss of light of 1 per cent. at a silvered surface, which is low, the loss of light in a pentaprism is about double the loss in a 90-degree prism. If the loss of light at a silvered-reflecting surface is taken at 3 per cent. to 5 per cent. the result is still more in favor of the 90-degree prism.

The loss of light due to absorption by glass in large prisms, added to the difficulty of obtaining large prisms, and their change of form with unequal heating due to temperature changes, has resulted in various substitutes for the large pentaprisms.

In the Cooke-Pollen range finder two mirrors are mounted on a substantial frame, as shown in Fig. 23.

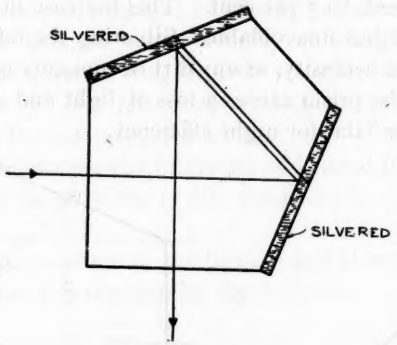


FIG. 23.

An examination of this figure shows that, at the first mirror, there are two reflections, one from the front face, the other from the silvered face; and hence two images would be seen. Where a second mirror is used, the double reflection at the second mirror annuls the double reflection at the first mirror and there is but one reflection from the construction as a

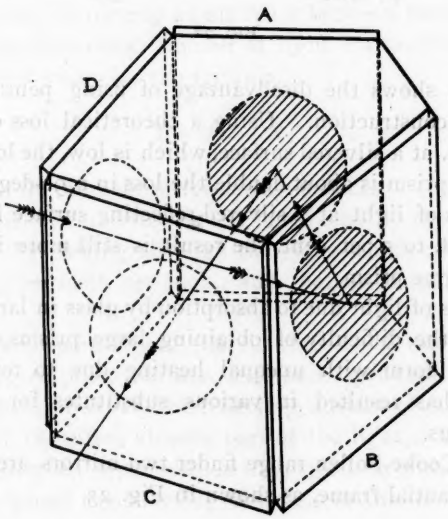


FIG. 24.

whole. The thickness of the mirrors is immaterial; the two faces of each mirror must, however, be perfectly parallel.

Fig. 24 shows a type of prism now being experimented with by the firm of Carl Zeiss, Jena. A block of glass or quartz has two holes bored through it as shown. Parallel-sided glass plates with the inside surface silvered and polished are cemented to the block at A and B. Two other parallel-sided glass plates are cemented to the block at C and D. The air inside must be thoroughly dry before the block is sealed up; otherwise, under certain atmospheric conditions, there would be condensation of moisture inside, with tarnishing of the silver surfaces. If these two disadvantages can be completely prevented, this type of prism would be about equal in efficiency to the Cooke-Pollen construction.

TEST OF LIGHT TRANSMISSION.

The light transmission of any optical system may be very accurately measured by means of Martens Photometer (Fig. 25 shows this instrument in section).

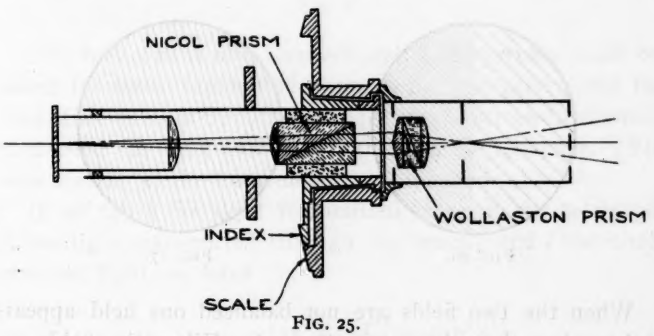


FIG. 25.

A uniformly illuminated screen is set up so that light from the screen will pass through the telescope and into the photometer.

The photometer is placed so that the optical axis of the telescope is in prolongation of one of the lines of sight pass-

ing into the photometer, and so that the eye point of the telescope is at the opening to the photometer. The exit pupil must be larger than and must cover the opening to the photometer. A small 90-degree prism is placed over the other opening to the photometer, and a second 90-degree prism is set up so that the light reflected by these two prisms into the photometer is taken from about the same place on the illuminated screen as the light which passes into the telescope.

The light from the two fields under comparison is polarized and made divergent by the Wollaston prism. The divergence is a little more than neutralized by the halving prism cemented to the rear of the Wollaston prism; the halving prism also eliminates the dividing line between the two fields. The Nicol prism and the eyepiece are mounted in a tube which rotates independently of the Wollaston prism. The eyepiece is focused on the apex of the halving prism.

Rotation of the Nicol prism balances the two fields; their relative intensities being proportional to the square of the tangent of the angle between the principal planes of the two polarizing prisms.

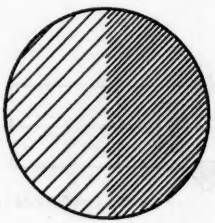


FIG. 26.

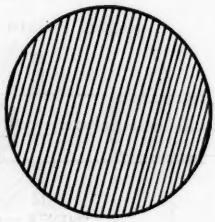


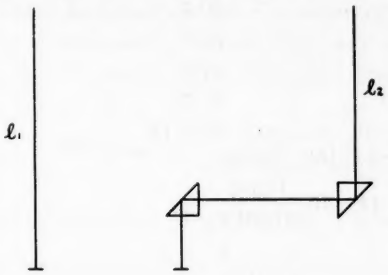
FIG. 27.

When the two fields are not balanced one field appears lighter than the other, as in Fig. 26. When the fields are balanced they appear of equal brightness, as in Fig. 27, and the line of demarcation disappears.

The method of using the photometer is shown diagrammatically in Fig. 28.

By the method of balancing the two fields described above

a comparison is made between the light transmitted through the telescope and the light transmitted through the two prisms, and the angle shown on the photometer scale read.



$\frac{l_1}{l_2} = \text{TAN}^2\,\varphi$

$\frac{l_3}{l_2} = \text{TAN}^2\,\varphi'$

$\frac{\text{TAN}^2\,\varphi}{\text{TAN}^2\,\varphi'} = \frac{l_1}{l_2} \times \frac{l_2}{l_3} = \frac{l_1}{l_3} = \text{TELESCOPE TRANSMISSION}$

l_1 = THROUGH TELESCOPE
l_2 = THROUGH PRISM
l_3 = THROUGH CLEAR

FIG. 28.

The telescope is now removed and a comparison made between the light transmitted through the two prisms and the unobstructed light from the same part of the screen from which proceeded the light transmitted through the telescope. The new reading of the photometer scale is noted.

If we call l_1 the light transmitted through the telescope; l_2 the light transmitted through the prism; and l the unobstructed light, we have

$$\frac{l_1}{l_2} = \tan^2\varphi \text{ and } \frac{l}{l_2} = \tan^2\varphi^1;$$

then

$$\frac{l_1}{l} = \frac{\tan^2\varphi}{\tan^2\varphi^1}.$$

In the case of a certain telescope tested recently, the following results were obtained:

R_1.	R_2.
47.4	57.
47.2	56.2
46.9	56.2
47.6	57.1
47.1	57.2
47.24 mean	56.74
47°–14′	56°–44′

$$47°\text{–}14' \tan .03389$$
$$56°\text{–}44' \tan \frac{.18307}{9.85082}$$
$$\frac{2}{9.70164}$$
$$\frac{l_1}{l} = .503.$$

Light transmission 50.3 per cent.

Under present conditions of manufacture, loss of light in telescopes has been reduced to a minimum and very little improvement can be made. The greater part of the light lost at a refracting surface seems to be due to reflection at that surface, and the more perfect the polish of the refracting surface, the better reflecting surface it will be. Considerable attention has been paid lately to processes of slightly etching the refracting surfaces in an endeavor to reduce the amount of light lost by reflection.

The makers of the Cooke-Pollen range-finder claim that, by such a method, they have reduced the amount of light lost at each refracting surface to a little less than 3 per cent. The details of their method are not available.

Section IV.

Stereoscopic (binocular) vision.

The following discussion of stereoscopic vision relates to both unaided binocular vision and to instrumentally-aided binocular vision, with especial reference to the Mark I spotting glass.

The following table is furnished by one of the leading foreign manufacturers of binoculars:

Table to Illustrate the Extension of the Field of Stereoscopic Vision with Unaided Eyes and with Binoculars, with and without Increased Stereoscopic Effect.

$$\text{Distance} = \frac{\text{Interpupillary distance}}{\text{Convergent angle}\,(\triangle)} \times \text{total plastic.}$$

Total plastic = Magnification × inter objective distance.

Convergent angle of the eyes. (△)	Unaided binocular = vision.	Aided binocular vision 7 × magnification.	
		Inter objective distance = interpupillary distance.	Inter objective distance = 2.1 interpupillary distance.
Total plastic.	1	7	14.7
30″ (limit).	440 meters.	3,080 meters.	6,468 meters.
1′ 00″.	220 meters.	1,540 meters.	3,234 meters.
1′ 30″.	147 meters.	1,029 meters.	2,160 meters.
2′ 00″.	110 meters.	770 meters.	1,617 meters.
2′ 30″.	88 meters.	616 meters.	1,293 meters.
3′ 00″.	73 meters.	511 meters.	1,073 meters.
3′ 30″.	63 meters.	441 meters.	926 meters.
4′ 00″.	55 meters.	385 meters.	808 meters.

Sixty-five millimeters is taken as the interpupillary distance in calculating this table.

The inter objective distance is the distance between the centers of the objective lenses. Calculation gives 446.9 meters in place of 440 meters as the first distance in the second column. All distances in columns 2, 3 and 4 should be changed accordingly if the exact results are desired. For the purpose of this discussion the tabulated figures are sufficiently accurate and will be adhered to.

While the above table is accurate, it is apt to be very mis-

leading unless studied with a clear understanding of the subject.

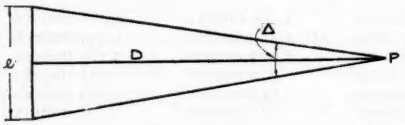
It may be stated that almost anyone possesses, or can acquire, the ability to see stereoscopically; the exceptions being those individuals who have a marked difference in the visual acuteness of the two eyes, or who are unconsciously accustomed to use one eye constantly to the exclusion of the other.

The ability to see stereoscopically depends upon the ability to turn the eyes in toward each other and is to a large extent a question of muscular control, and hence will improve with practice.

By the exercise of the stereoscopic function, the normal individual is enabled to distinguish clearly a difference in depth of 30″, and in the case of individuals having marked visual acuteness this difference can be reduced, with practice, to 10″.

Referring to column No. 1 of the table:

△, or the convergent angle of the eyes is illustrated by Fig. 29, where



E = 65 MM
Δ = 30″
D = e / TAN Δ

LOG. 65 = 1.81291
LOG. TAN Δ = 6.16270
LOG. D = 5.65021

D = 446900 MM
= 446.90 M

FIG. 29.

e = interpupillary distance.
D = distance of stereoscopic vision.
△ = the convergent angle.

D is obtained by the formula,

$$D = \frac{e}{2 \tan. \frac{1}{2} \triangle}.$$

Where △ is small, as it usually is, this formula, for all practical purposes, becomes,

$$D = \frac{e}{\tan. \triangle};$$

440 meters in round numbers.

This stereoscopic distance does not mean that the stereoscopic ability of the normal eyes enables one to judge which of two objects close to each other and at a distance of 440 meters is farther away. It means that 440 meters is the radius of the stereoscopic field for the normal eyes; *i.e.*, the greatest distance at which an object P viewed under a convergent angle of 30″ will stand bodily out from space beyond. For the value $\triangle = 30''$ there will be no visible relief effect for any object at any distance behind P. The normal eyes would be unable to discern any depth beyond 440 meters, and hence any objects lying farther away than P would appear to lie in the same plane as P, this plane being perpendicular to the line of sight.

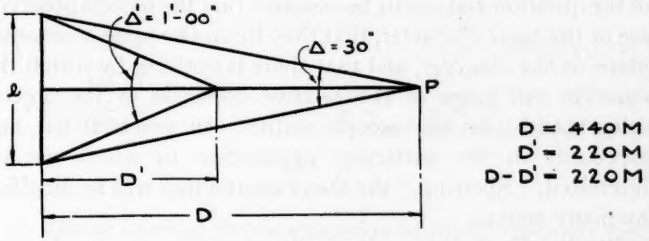


FIG. 30.

An examination of the table and of Fig. 30 will show that as 30″ is the smallest angular change that is perceptible, an object similar in form will have to move in to the point P^1, a distance of 220 meters, before it would be separated from P. Then $D - D^1 = 220$ meters and is the smallest change of range that could be detected under the conditions we have chosen. If by practice the stereoscopic function of the normal eyes is increased so that 10″ angles can be discerned, our stereoscopic ability increases as shown in Fig. 31, where, as before, D=440 meters. D″, the limit of distance at

which a point would be stereoscopically visible, would be increased to 1,320 meters roughly, and D—D¹ would be reduced to 73 meters as the smallest change of range that we would be able to detect at 440 meters.

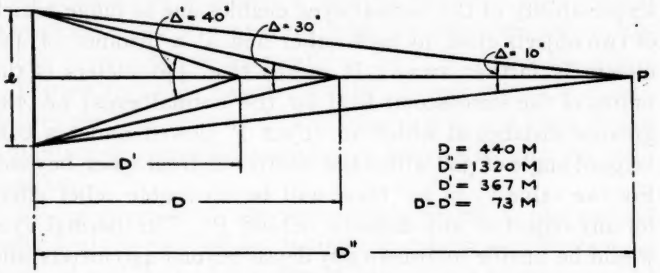


FIG. 31.

A disgression is necessary at this point to state that this discussion will be confined strictly to the stereoscopic aspect of the question and it will be assumed that the objects observed are of the same character, that they lie in the same horizontal plane as the observer, and that there is nothing by which the observer can judge of the relative distances of the objects other than by his stereoscopic ability. In practical use, and especially in the particular application in which we are interested, "Spotting," the above assumption will be modified by many factors.

The height of the spotting position will enable the observer to judge the relative distances of a splash and the target.

If the target is hidden by the splash or the splash is partly hidden by the target, their relative positions are known regardless of the stereoscopic effect.

From long training, the relative distances of objects can be judged to a certain extent by their appearance.

Referring again to the table, the assumption that the extension of the field increases directly with the magnification and with the increase of objective distance is correct. If the limit of stereoscopic visibility with the unaided normal eyes

is 440 meters, a binocular with an objective distance of 65 mm. and a magnification of 10 would increase this limit to 4,400 meters, and if the divergent angle of the unaided eyes was 30″, with the above magnification, this angle would be decreased to 3″. Accordingly, with these binoculars, at 440 meters, a decrease of range of roughly 34 meters or an increase of 56 meters would be discernable, as shown in Fig. 32.

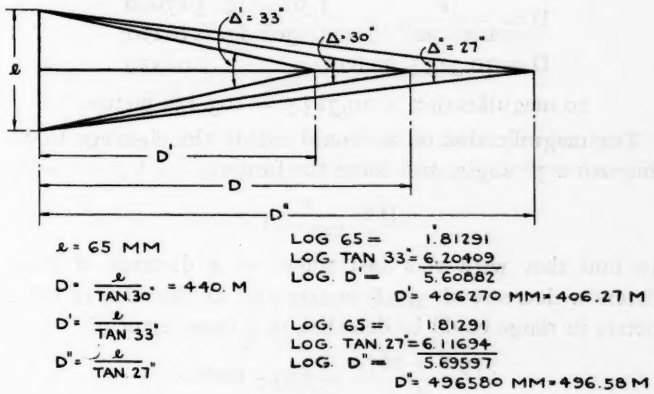


FIG. 32.

A similar increase in the extension of the stereoscopic field is obtained by increasing the objective distance. Attention is here called to the fact that increase of objective distance increases the limit of stereoscopic visibility in direct proportion, but does not enable the observer to distinguish any smaller angle at the point observed. Increase of magnification, on the other hand, increases the limit of stereoscopic visibility and enables the observer to distinguish smaller angles, both in direct proportion.

All prisms binoculars have more or less stereoscopic effect when compared with the normal eyes. This is readily seen by comparing the distance between the centers of the objective

lenses and the centers of the eye lenses (interpupillary distance).

With the Mark I Spotting Glass with the 1.5 meter objective distance, and using the magnification of 10, the limit of stereoscopic visibility would be increased about in proportion of

$$440 : \times = 65 \times 1 : 1{,}500 \times 10$$
$$\times = 101{,}538 \text{ meters.}$$

The use of the formula gives about the same result.

$$D = \frac{e}{\text{tan. } 30''} = \frac{1{,}500}{\text{tan. } 30''} \quad \begin{array}{l} \text{lg. } 3.17609 \\ \text{lg. } 6.16270. \\ \hline 7.01339 \end{array}$$

$D = 10{,}323.5$ meters

10 magnification $\times$ 10,323.5 = 103,235 meters.

The magnification of 10 would enable the observer to distinguish a 3″ angle, and using the formula

$$D = \frac{e}{\text{tan. } \triangle},$$

we find that with this instrument at a distance of 8,000 meters a decrease of 579.8 meters and an increase of 667.2 meters in range could be detected, or a mean error of

$$\frac{579.8 + 667.2}{2} = 623.5 \text{ meters,}$$

as shown in Fig. 33.

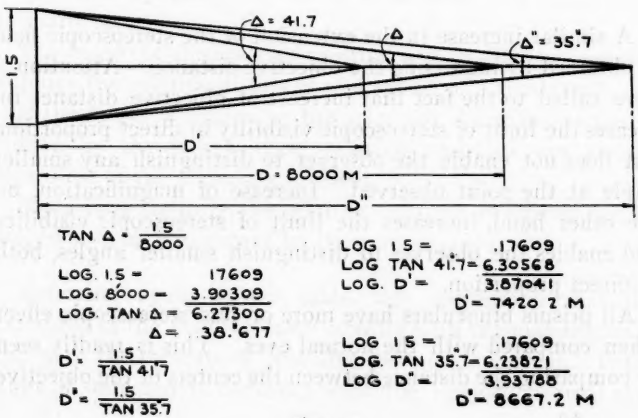


FIG. 33.

A more ready method of obtaining the depth at any distance is by the use of the formula giving the errors expected in the stereo range finder.

$$d\,E = \frac{E^2\delta}{BV} = \frac{E^2}{R} \text{ where } R = \frac{BV}{\delta} = r \times \frac{B}{A} \times V,$$

$\frac{B}{A} \times V$ = the total relief effect.

A = interpupillary distance.

B = objective distance.

V = magnification.

r = radius of stereo field with normal eyes.

$$r = \frac{A}{\tan \delta} = 440 \text{ meters where } \delta = 30''.$$

Using this formula, the least error of the 1.5 meter spotting glass Mark I with 10 magnification at 8,000 meters would be:

$$d\,E = \frac{E^2}{r \times \frac{B}{A} \times V}$$

$$= \frac{8{,}000 \times 8{,}000}{440 \times \frac{1.5}{\frac{65}{1{,}000}} \times 10 \text{ meters}}$$

$$\frac{8{,}000 \times 8{,}000 \times 65}{440 \times 1.5 \times 1{,}000 \times 10} = 630 \text{ meters},$$

which agrees very closely with the result of the calculations accompanying Fig. 5. That is, unless two objects at about 8,000 meters range were separated by at least 630 meters the observer using the Mark I Spotting Glass could not detect any difference in depth between the two objects, and both would appear equally distant. The error of this instrument at 440 meters is worked out here. Error of 1.5 meter Mark I Spotting Glass at 440 meters:

$$d\,E = \frac{E^2}{r \times \frac{B}{A} \times V} = \frac{440 \times 440}{440 \times \frac{1.5}{\frac{65}{1{,}000}} \times 10} = 1.91 \text{ meters.}$$

It must likewise be remembered that this is the theoretical error, and that other than perfect atmospheric conditions would increase this error. It must also be remembered that while by the exercise of the stereoscopic function the relative distances of objects can be determined within the limits stated above, corrections for spotting could not be determined therefrom, as the observer would have no known base to which to refer his discerned difference in depth of the target and the splash.

It is not believed that the stereoscopic effect in itself would be of any great value in spotting, but is it considered that it will increase the accuracy of spotting as now carried out, especially as spotters become more familiar with the use of the Mark I Spotting Glass.

One battleship in the Atlantic Fleet reported that there was no advantage due to the stereoscopic effect of the Mark I Spotting Glass over the ordnance binocular. This perhaps should be considered as having reference to the vertical method of spotting.

The value of the Mark I Spotting Glass is undoubtedly due to several factors: to the optical excellence of the instrument, to its being mounted on a stand, to the satisfactory control in elevation and azimuth, and to its stereoscopic effect.

METHOD OF MENDING CRACK IN CYLINDER FLANGE.

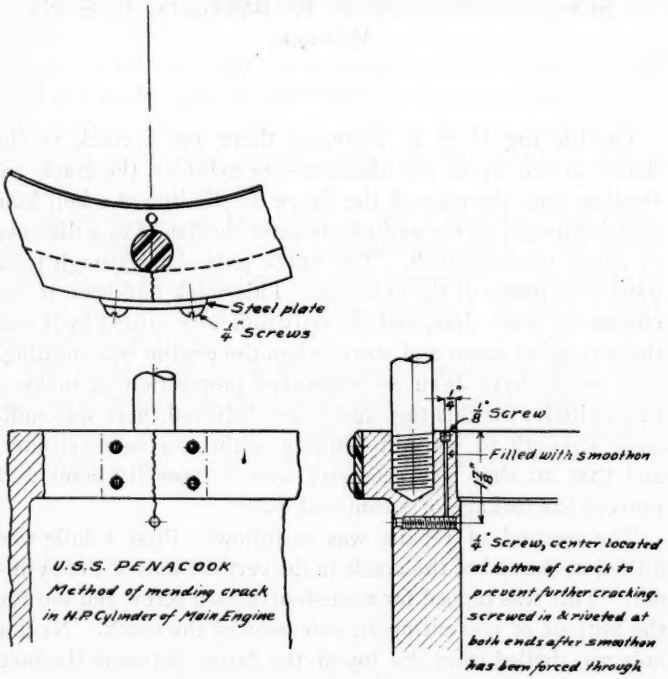
SUBMITTED BY CAPT. F. W. BARTLETT, U. S. N., MEMBER.

On the tug U. S. S. *Penacook* there was a crack in the flange at the top of the high-pressure cylinder, the crack extending from the edge of the flange on the line of a bolt hole and downward on the cylinder beyond the flange to a distance of about one-half inch. The crack extended through from outside to inside of the cylinder. This crack had been in existence for some time, and the only difficulty caused by it was the leakage of water and steam when the engine was running.

It would have been an expensive proposition to make a new cylinder for this tug, and it was believed there was sufficient strength to warrant running without a new cylinder, and that all that was necessary was to close the crack and prevent the leakage of steam and water.

The method of repairs was as follows: First a hole was drilled at the end of the crack in the vertical wall of the cylinder. This was tapped for a one-fourth-inch screw and was for the purpose of preventing an extension of the crack. Next a hole was drilled from the top of the flange between the bolt hole and the cylinder wall to the depth of the hole previously drilled at the end of the crack. The new hole was for a one-eighth-inch screw and joined the first one. The hole at the base of the crack was filled by a screw. Smoothon cement was poured into the smaller hole until the hole was full, then a screw was inserted and screwed down on top of the smoothon, forcing it into the crack in all directions. The smoothon soon appeared at the part of the crack below the flange, and finally

appeared to a slight extent in the crack at the top of the flange, though the principal effect shown there was that of water oozing up through the crack. This last screw mentioned was cut off flush and the screw at the end of the crack was riveted over inside and out. Then a steel plate, previously prepared, was screwed on the edge of the flange overlapping


Steel plate
¼" Screws
⅛" Screw
Filled with smoothon
¼" Screw, center located at bottom of crack to prevent further cracking. screwed in & riveted at both ends after smoothon has been forced through
U.S.S. PENACOOK
Method of mending crack in H.P. Cylinder of Main Engine

the crack on both sides. The idea of the last plate was to prevent the outer rim of the flange from expanding, due to heat, and to prevent the crack opening and dislodging the smoothon. The smoothon was dry in a short time, and within a day the engine was operated and has been running for a week, with no sign of leakage of water or steam.

The accompanying sketch makes the operation clear.

THE DYNAMICAL EQUIVALENT OF HEAT.

By Rear Admiral John Lowe, U. S. N., Retired, Member.

In very many quarters of the scientific world there has arisen a great diversity of opinion as to the value of the dynamical equivalent of heat, some holding to one value, while others accept quite different values.

The object of this essay is to prove in elementary fashion, that there is no occasion for this diversity, but that, on the contrary, experiments conducted at widely-separated times, places and circumstances, by authorities, each as widely separated, all concur in reaching one conclusion, should be accepted as a convincing fact, forbidding dissent.

(1) By U. S. law one kilogramme is equal to 2.2046212 pounds avoirdupois.

(2) One calorie is the heat unit contained in one gramme of water, elevated in temperature, one degree centigrade.

(3) One thermal unit (one B.t.u.) is the heat contained in one pound of water elevated in temperature, from 50 degrees to 51 degrees Fahrenheit, one degree.

Seeing that it takes 1.8 degrees Fahrenheit to equal one degree centigrade, it follows that one (B.t.u.) equals

$$\frac{1{,}000}{2.2046212 \times 1.8} = 251.97 \text{ calories.}$$

(4) The work which can be performed by one horse is, by watts, defined to be, 33,000 foot pounds per minute. By common consent this has become the standard work unit.

(5) Another authority declares that the electric work unit of 746 watts, or in better words (746 volt ampères), is exactly

equivalent to 33,000 foot pounds, and that volt ampères are exactly analogous to foot pounds.

(6) Joules Law is declared to be an experimentally-determined fact, or law of nature. It is expressed by the equation $H = kWt$, in which H = heat in calories; W = volt ampères; t = time, in seconds; (k) is a co-efficient, practically equal to 0.24; scientifically = 0.24066.

(7) The celebrated experiments made in Manchester, England, indicate that 772 foot pounds is the mechanical equivalent of one thermal unit. Consequently, in 33,000 foot pounds per minute there are $\frac{33,000}{772}$ thermal units per minute, or $H = \frac{33,000 \times 1,000}{772 \times 2.2046 \times 1.8}$ in calories per minute. Now, then, all these diverse and separate statements thus enumerated are either false and worthless or else, being true, they are each and all corroborative the one of the other, and therefore H in (6) is exactly equal to H in (7); that is to say,

$0.24066 \times 746 \times 60 = \frac{33,000 \times 1,000}{772 \times 2.2046212 \times 1.8}$ calories per minute, or 10,771 calories = 10,771 calories per minute. Now, much more can be said by way of argument, but more would be too much, for there is here proof positive that the above-enumerated statements are each and all exactly true.

Before parting with the subject there is this much yet to say:

Electric science is overburdened with too many units. In practice, volts, ampères and ohms alone are considered; coulombs and joules are never mentioned. They should therefore, in like manner, disappear from the text books, and thus allow electric science to become easier to learn.

THE PRESENT STATUS OF AIR SHIPS IN EUROPE.*

Reprinted from "Journal Franklin Institute," June, 1914.

By Jerome C. Hunsaker, Assistant Naval Constructor, U. S. Navy.

Instructor in Aeronautics, Massachusetts Institute of Technology.

I. GENERAL.

During the past three years aeronautics has developed from the field of invention into that of engineering. Air craft are no longer invented out of pure speculation, but are designed according to engineering principles from the formulæ of the research laboratory and the data of the testing laboratory. A type is only new in the matter of the application of well-known principles, and is in the nature of an improvement and perfection of existing types. The requirements of military and naval authorities and the conditions of prize contests have created a demand for an engineer to design air craft to meet given specifications. There has thus evolved a new technician, the aeronautical engineer. The air craft of 1913 are principally to be distinguished by the evidence of engineering skill in their design and construction.

Recognition by the public of the value of air craft in national defence has led to the development of an industry devoted to the supply of dirigibles and aeroplanes. Especially in France and Germany has aeronautics been stimulated in this manner. France developed the first practical dirigibles, but has until recently concentrated her energy chiefly upon aeroplanes, with the result that at the present time the French

*Communicated by the author.

army is estimated to have between 500 and 1,000 aeroplanes in service. These aeroplanes are, moreover, of types that represent the highest development in aeroplane design. On the other hand, Germany, realizing the menace of this aerial force and the impossibility of duplicating it, has recognized the possibilities of the dirigible and given liberal support to the development of the ships of Count Zeppelin and Major von Parseval. Great sums have been spent and many lives have been lost, but the reward has already come. The German army now possesses a splendid fleet of 25 air ships, representing the highest development in air-ship design. At the same time, France has brought her fleet of air ships up to 18, and Germany has some 200 military aeroplanes with a large civilian reserve. It has become a race for the supremacy of the air between two great powers whose capitals lie within the radius of action of air craft from each other.

England has recently joined the race for supremacy, and, apparently realizing that it is too late to overtake her continental rivals by the mere multiplying of units, has directed every effort toward the development of air craft superior in design to the existing types. Foreign machines have been purchased liberally, and an aerodynamic laboratory and an experimental air-craft factory have been built. England's future in aeronautics is placed in the hands of an Advisory Committee headed by Lord Rayleigh and composed of distinguished scientists and engineers. The race then is not only between the factories but also between the laboratories. The production of a type of marked superiority will immediately make obsolete the aerial forces of other powers.

This rivalry between the great military powers is a most fortunate thing for the art, for in no other way could such intense interest in its problems be created. In laboratories, shipyards and factories able men are working to improve the safety and reliability of aerial transportation with a devotion and intelligence that must lead to substantial advance in the general utility of air craft.

II. DIRIGIBLES.

Dirigible balloons are self-propelled air ships in which the lifting force is given by a gas-filled envelope beneath which cars are suspended for the accommodation of the power plant and passengers. In the rigid type the envelope is held in shape by a rigid frame. In the non-rigid type the envelope is held in shape by internal gas pressure. A third type, the semi-rigid, seeks to provide a rigid frame only about the lower part of the envelope. The relative merits of these types can best be discussed after considering their qualities more in detail.

FRENCH DIRIGIBLES.

The non-rigid dirigible was developed in France, between 1885 and 1900, by Renard, Krebs, Juillot and Santos-Dumont, and has followed closely the improvement of the gasoline motor. At the present time ships of the non-rigid type are being built by the Astra Society (M. Surcouf), Zodiac, Clement Bayard, Lebaudy and Godart. One wood-framed rigid Speiss dirigible is building at the Zodiac works.

ASTRA DIRIGIBLE (FIG. 1).

The Astra Society, of which the engineer E. Surcouf is director, has recently purchased the Torrés patents and is building ships of remarkable speed and elegance of design.

Envelope.—The envelope built on the Torrés system consists of three lobes in which the indentations or cusps run longitudinally. It has the appearance in general of a cucumber or an elongated cantaloupe. The internal gas pressure fills out the lobes, which have their cusps tied together by internal rope rigging. The ropes are, therefore, always in tension. Longitudinally, heavy ropes run from bow to stern along the inside of the cusps. The result is a long girder all of whose parts are in tension. The longitudinal strength so given the envelope makes it possible to moor such a ship to a post in the open by means of a cable from the nose. There is, of

course, the extra weight of internal rigging over the envelope of ordinary fish-shaped form, and the lobed cross-section presents more surface per given volume than a circular section. However, the heavy belly-band and external rigging between car and envelope are avoided in the Astra-Torrés type and considerable head resistance saved. Furthermore, the total weight of the car comes upon the internal rope rigging and does not tend to strain the envelope. The envelope can then be made of lighter material than in the ordinary type. There is an additional advantage claimed from the fact that in any envelope subject to internal pressure the stress in the fabric varies as the radius of curvature at any point. The radius of curvature is less in a lobed cross-section than in a circular one for a given total area of section.

Suspension.—The car is suspended below the envelope by vertical steel cables. The use of external rigging and crow's feet is entirely avoided, as the weight is taken directly by the interior rope girder and thence distributed to the envelope.

Car.—The car can be made very short without causing the back of the envelope to sag. The weight is evenly distributed by the internal roping. The car is covered with fabric or sheet metal. Its framing is an elastic structure of steel tubing, easily taken apart for shipment or stowage aboard ship.

Motors.—Water-cooled motors of various commercial types have been employed. Usually two units are installed for the sake of reliability. In view of the elastic nature of the car, it is not considered necessary by the builders to mount the motors on springs.

Propellers.—Either or both motors may drive either or both propellers through proper clutches, reverse clutches, and gearing. Two wooden propellers are carried on brackets of steel tubing projecting upward and outward from the car. The propeller axis is raised so that the center of thrust may come nearer the center of head resistance, and so that when the car is on the ground the whirling blades are no menace to the heads of bystanders.

Gas Pressure.—Hydrogen gas 15 mm. above atmospheric

pressure fills the envelope. It may be noted here that hydrogen is now used in all air ships. A lifting force of 1.12 kg. per cubic meter of gas 99 per cent. pure may be counted on.

Swivelling Axis.—The propeller axes are mounted in such a manner that they may be movable in a vertical plane parallel to the center line of the ship. This is of assistance near the ground and in maneuvering.

Stability.—Static stability is given as in all air ships by having the center of gravity below the center of buoyancy. The usual methods of naval architecture may be applied to the calculation of stability. Stability of route is given by the envelope form fitted with a vertical fin aft. The center of side resistance is thus placed abaft the center of gravity. The ship is steered by horizontal and vertical rudders on the after part of the envelope. Equilibrium in altitude is adjusted by the use of water ballast and a relief gas valve. The practice in free ballooning is followed. In descending from a high altitude gas must be allowed to escape in order to reduce the lift. As the ship descends the gas pressure of 15 mm. is kept constant by inflating internal air sacs or ballonets. The ballonets are connected by a duct of fabric to a blower in the car operated by the motors, or by hand in an emergency.

The following particulars of the naval type Astra-Torrés purchased by the British Admiralty are given as illustrative:

Type, Astra-Torrés XIV, Scout.

Volume in cubic meters	7,500
Speed, kilometers per hour	82.2
Length, meters	75
Height, meters	21
Diameter, meters	14
Useful lift, kilos	2,500
Crew	5
Radius of action, in hours	12
Ballast, kilos	315
Cars	1
Propellers	2
Power, horsepower	400

This ship made a speed 51.1 miles per hour on her acceptance test, the world's record for dirigibles.

The company has under construction two ships of 24,000 meters cube in which it is expected 12 men may be carried 20 hours at over 80 kilometers per hour. Four 250-horsepower motors will drive four propellers.

Zodiac Dirigible.—The Zodiac Company builds non-rigid dirigibles in which the envelope is a solid of revolution below which the car is suspended. A heavy canvas belly-band is sewed to the bottom of the envelope. From toggles in this band hemp crow's feet lead to wire rope rigging attached to the car. In order to distribute the load uniformly to the envelope the car is made long and narrow.

The horizontal rudder for control of elevation is mounted on the forward part of the car. In this position the rudder throws no force on the flexible tail of the envelope and also gives considerable lift by its aeroplane effect. The ship can thus be caused to ascend without loss of ballast.

The following details are given of their latest ship:

Type, Fleurus Amélioré.

Volume, cubic meters	14,000
Speed, kilometers per hour	79
Length, meters	100
Diameters, meters	16
Crew	12
Radius of action, hours	20
Cars, length 26 m	1
Propellers	3
Motors, Zodiacs	3
Power, horsepower	675
Altitude, meters	1,800

In case of a forced landing without assistance an anchor with 150 meters of line can be thrown out to hold the ship head to wind.

Two machine guns are mounted on the car and one on a platform on the top of the envelope, reached by a ladder running through a trunk in the envelope.

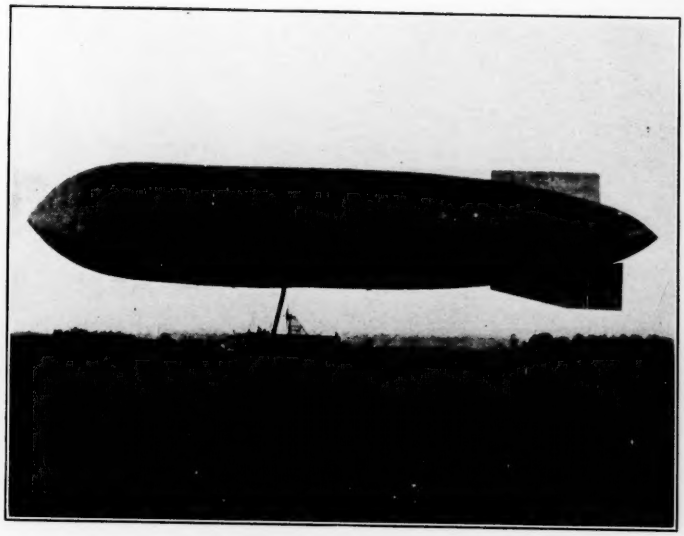


FIG. 1.—ASTRA-TORRÉS NON-RIGID DIRIGIBLE.

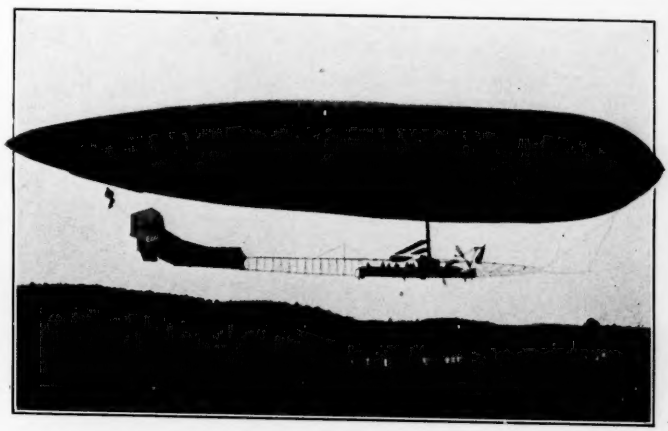


FIG. 2.—CLEMENT BAYARD NON-RIGID DIRIGIBLE.

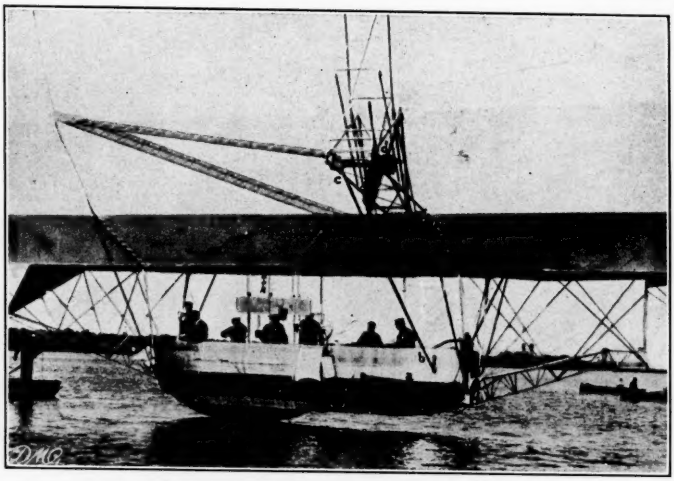


FIG. 3.—FORWARD GONDOLA OF ZEPPELIN.

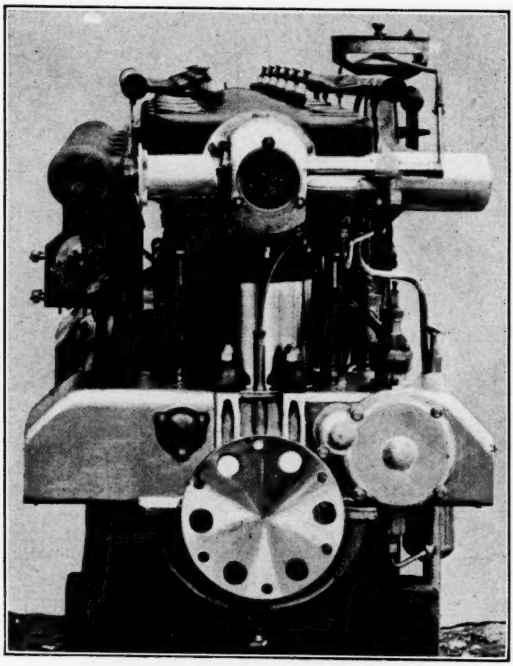


FIG. 5.—MAYBACH MOTOR.

CLEMENT BAYARD (FIG. 2).

Dirigibles built by this firm have the benefit of the resources of one of the greatest automobile plants in France. Their situation industrially is interesting, and well worth considering by American firms contemplating air-craft manufacture. In the Clement Bayard factory, when air-ship building is slack, the skilled and experienced mechanics are absorbed in other departments of the works as machinists, erectors, upholsterers, etc.

The principal features of Clement Bayard ships are:

(1) Variable-pitch propellers for reversing or changing speed. It is considered that the propellers can be worked at high efficiency, both at full and half power, by properly adjusting the pitch.

(2) A vertical lifting propeller of variable reversing pitch absorbs some 50 horsepower from a shaft geared to the main motors. This propeller is used in getting away from the ground, or to check downward velocity in landing. It is in many ways a simple substitute for swivelling propeller axes.

(3) An aeroplane surface over the center of gravity of the car can be moved in inclination by the pilot. The lift of this plane assists in climbing.

The French army possesses three large Clement Bayard airships, besides the *Adjutant Vincenot* and *Deputy de Lôme.*

The following details are given of a scout type supplied to the French army:

Type, Scout.

Volume, cubic meters	6,500
Speed, kilometers per hour	60
Length, meters	73.5
Diameter, meters	12.2
Fabric	Double diagonal, rubberized.
Radius, hours	15
Cars, length 10 m., width 1.8 m	1
Propellers, variable pitch for propulsion	2
variable pitch for ascension	1
Motors, Clement Bayard on springs	2

Power, horsepower	180
Altitude, meters	2,000
Ballonet volume, meters cube	2,400
Blowers	2

Self-starter on motors. Sand ballast.

GERMAN DIRIGIBLES.

Zeppelin Rigid Dirigibles (Figs. 3, 4, 5, 6).—In Germany the development of air ships has been greatly encouraged by the attitude of the army. The Zeppelin Company, manufacturing the rigid-type Zeppelin dirigible at Friedrichshafen, as well as the Delag Company, operating passenger Zeppelins, have been heavily subsidized. In return for such financial support these companies are pledged to secrecy as to the construction of the ships.

It is likely, however, that the construction is in no way mysterious and is based on sound engineering practice and a great deal of experience gained from long and costly experiment, great failures, and appalling accidents. The essential feature is an aluminum alloy for the frame which is both light and tough. Naturally the composition of this alloy is kept secret.

The hull of the Zeppelin ships consists of a long frame of aluminum alloy bars and steel wires made up of longitudinal members tied together at intervals by some 18 to 20 wheel-like transverse partitions. In each of the sections so formed a gas bag of gold-beater's skin is enclosed. The whole is enclosed in a linen waterproof non-gastight cover stretched over the frames. Each gas bag is fitted with a relief valve, spring loaded, or operated from the pilot's stand in the forward car. Gold-beater's skin is found to be more impervious to hydrogen than any other material used to date. It is, however, low in tensile strength and can only be used to advantage on the dirigible air ship when the gas is only slightly above atmospheric pressure. In the non-rigid ships the form is preserved by the inner pressure and rubberized fabric must be used. The hydrogen leakage in such case is about one per cent. in 24 hours under the best conditions, and is frequently greater.

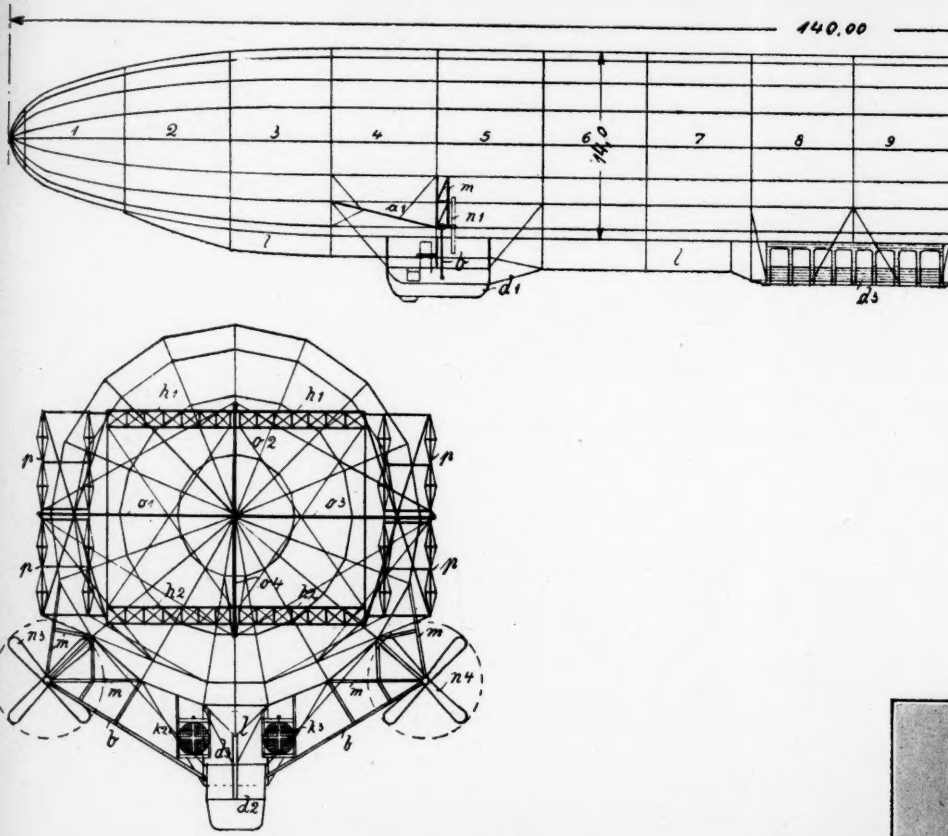
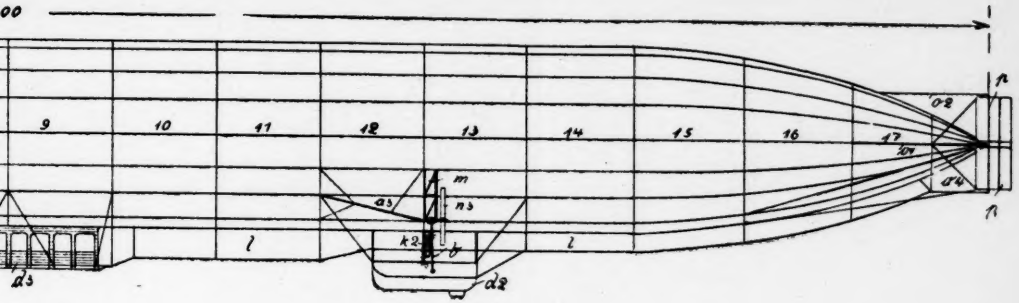
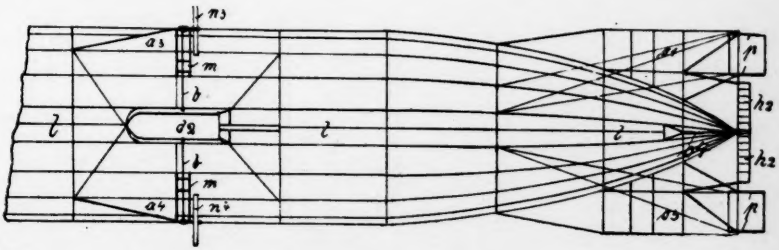
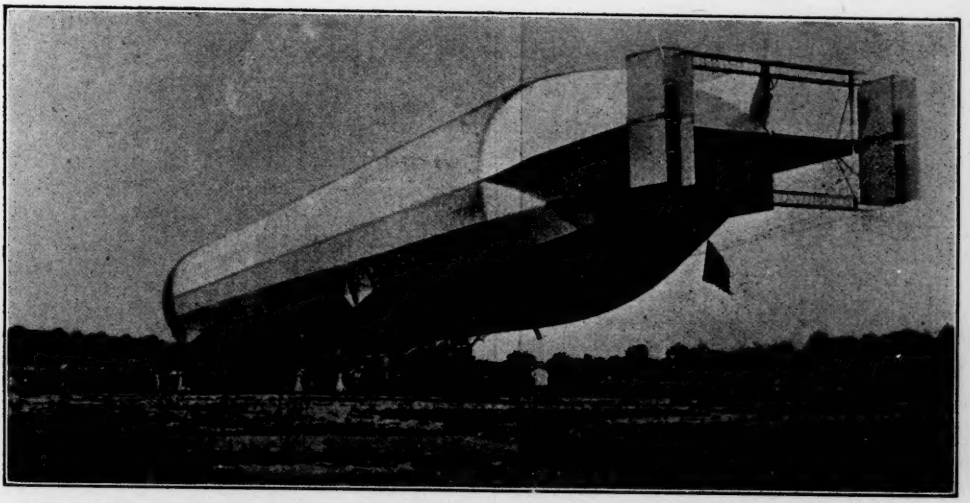


FIG. 4.—PLANS AND PHOTOGRAPHS OF THE







PHS OF THE PASSENGER ZEPPELIN "SCHWABEN."

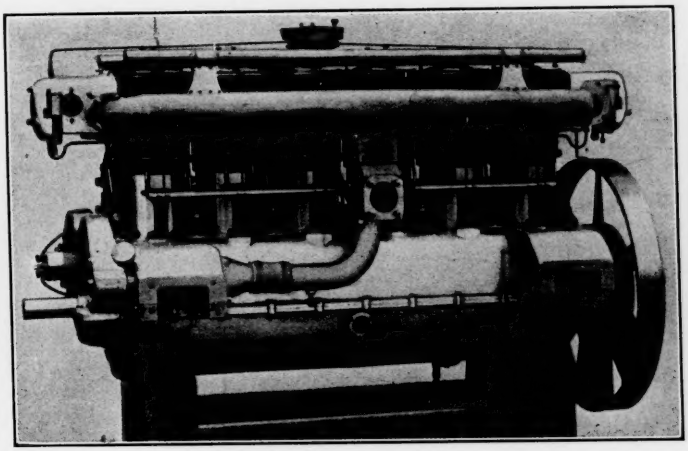


FIG. 6.—MAYBACH MOTOR.

Cars or gondolas are secured beneath the hull of the Zeppelin dirigible forward and aft. These cars are rigidly attached to the overhead framing and are very close to the envelope to diminish head resistance. There is also a middle car for the accommodation of passengers, armament, or freight. The power plant is carried in the forward and after cars.

The *motors,* three or four in number, are of special design for reliability and smooth running. All Zeppelins are now equipped with Maybach motors made by a subsidiary company. These motors have recently been put on the market and are used by the Parseval air ships. They are made in 200- and 300-horsepower units, 6 cylinders, water-cooled, double Bosch low-tension ignition, forced lubrication; 1,100 to 1,300 revolutions per minute; material special alloy steels; gasoline consumption .228 kilogram per horsepower hour, oil consumption, .015 kilogram per horsepower hour; weight of 200-horsepower motor, with cooling and ignition systems, 425 kilograms. These motors, on account of their even running, need not be mounted on springs. They operate well at reduced power, but usually when it is desired to reduce power one motor is stopped and the other worked full power.

Control.—The ship is steered by horizontal and vertical rudders attached to the rear of the hull and operated from the forward gondola. The ship can operate with a slight negative buoyancy due to the dynamic lift of the air upon the under side of the envelope when driven at full power in an inclined position. To balance with engines stopped, ballast and gas valves must be handled as in other air ships. As the ship ascends gas is automatically released from each gas bag. The pilot can open 8 gas valves at once if he wishes to descend. Stability of route is given by a proper arrangement of fins on the rear of the hull. Water ballast is carried in tanks near each of the three cars. It can be discharged from the pilot station by manipulating the valves. Before a landing the motors are stopped, and if, when way is lost, it is observed that the head is heavy, the pilot opens the valve of the

forward tank and discharges water until the ship comes to an even keel.

Propellers.—The propellers are mounted on side brackets. The two forward propellers are two-bladed and run at one-half the speed of the two after propellers, which are four-bladed. By use of clutches any propeller can be reversed or stopped regardless of the others.

The following details of the naval *Zeppelin L1,* lost in a gale over the North Sea, September, 1913, were published after the accident and are considered trustworthy:

Volume, cubic meters	22,000
Length, meters	160
Diameter, meters	15
Speed, kilometers per hour	85
Gas bags, gold-beater's skin	18
Radius of action, hours (at reduced power)	55
Power, horsepower, in three Maybach units	500
Weight, kilograms total	27,000
Net lift, kilograms	7,500
Fuel and oil, kilograms	3,000
Crew	17

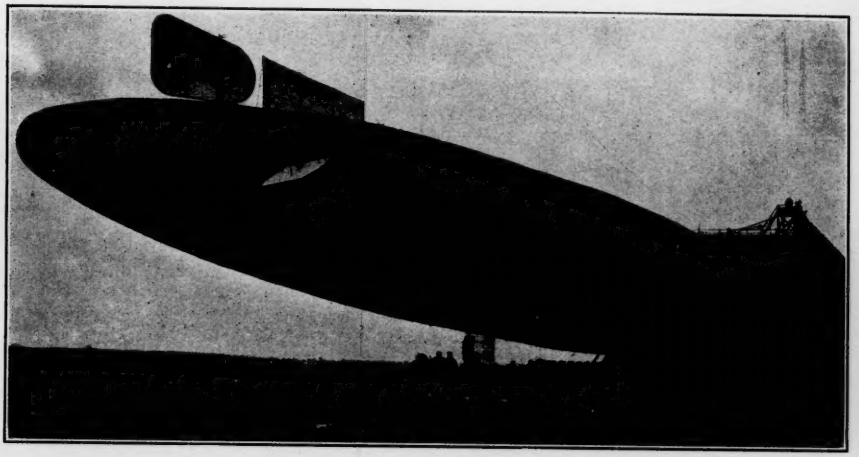
The crew was made up as follows:

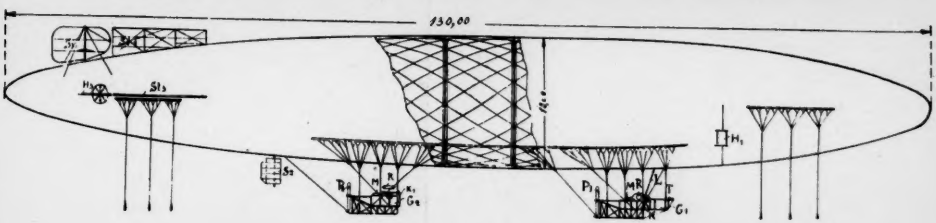
1 naval officer, commanding.
1 engineer officer, chief engineer.
1 quartermaster, vertical rudder.
1 quartermaster, horizontal rudder and valves.
2 quartermasters, relief for above.
1 radio operator.
1 relief for above.
3 machinists.
3 relief machinists.
3 extra men, passengers and gunners.

The second naval *Zeppelin L2* represented the latest development of the type, and before she met with an accident on her acceptance trial was reported to have attained a speed of 60 miles per hour with 900 horsepower. The volume was 27,000 cubic meters, and radius of action estimated at 70 hours at reduced power.

Schütte Lanz (Fig. 7).—The rigid Schütte Lanz air ship

FIG. 7.—SCHÜTTE LANZ WOOD-F





...NZ WOOD-FRAMED RIGID DIRIGIBLE.

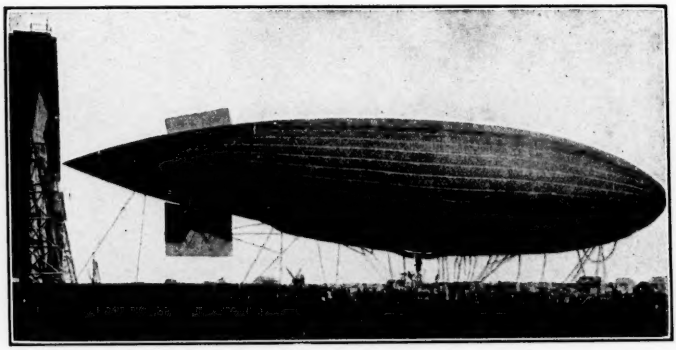


FIG. 8.—PARSEVAL NON-RIGID DIRIGIBLE.

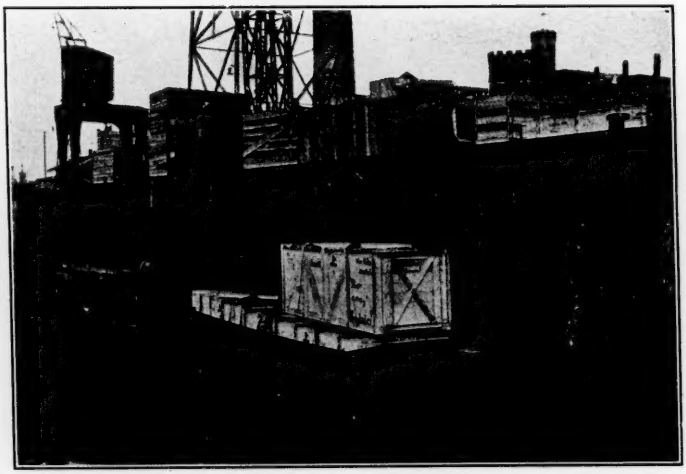


FIG. 9.—PARSEVAL DIRIGIBLE OF FIG. 8 BOXED FOR SHIPMENT TO JAPAN.

differs from the Zeppelin in having its frame made of wood. It is hoped that this construction will be lighter and tougher than metal and that the ship will not be so easily injured by contact with the ground as are the Zeppelins. The details of construction are not made public.

Parseval Dirigible (Figs. 8 and 9).—The non-rigid German air ship is represented by the Parseval. In 1906 the Luft Fahrzeng Gesellschaft was formed to take over the patents of Major Professor Dr. A. von Parseval and to construct and develop non-rigid air ships. A research laboratory was endowed at the University of Göttingen and practical experiments undertaken at the works in Bitterfield. To date 20 ships have been built, and there have been no serious accidents. One ship was destroyed in its shed by fire due to carelessness.

The principal characteristic of the Parseval ship is that it has had its design based on engineering tests. The torpedo-shaped form of the envelope is the result of tests at Göttingen to obtain a shape giving the least head resistance for a given volume. The arrangement of fins and rudders for stability of route and control was also studied by the use of small models in the Göttingen wind tunnel. The strength of envelope fabric required is determined from the known pressure distribution about the hull in motion, as found by wind-tunnel tests at Göttingen, together with the known physical properties of the fabric as given by the testing machine.

The calculation of the bending moment in the envelope and the suspension of the car may be of interest. Only the general procedure can be given here. The method is described in detail by Haas and Dietzins in "Stoffdehnung und Formänderung der Hülle von Prall Luftschiffen," published by J. Springer, Berlin.

STRENGTH CALCULATION FOR DIRIGIBLE (NON-RIGID).

Buoyancy Curve.—Erect a curve representing the buoyant force of the envelope. Such a curve has ordinates proportional to the cross-sectional area at each point along the length of the envelope. This curve is shown in Fig. 10 as B.

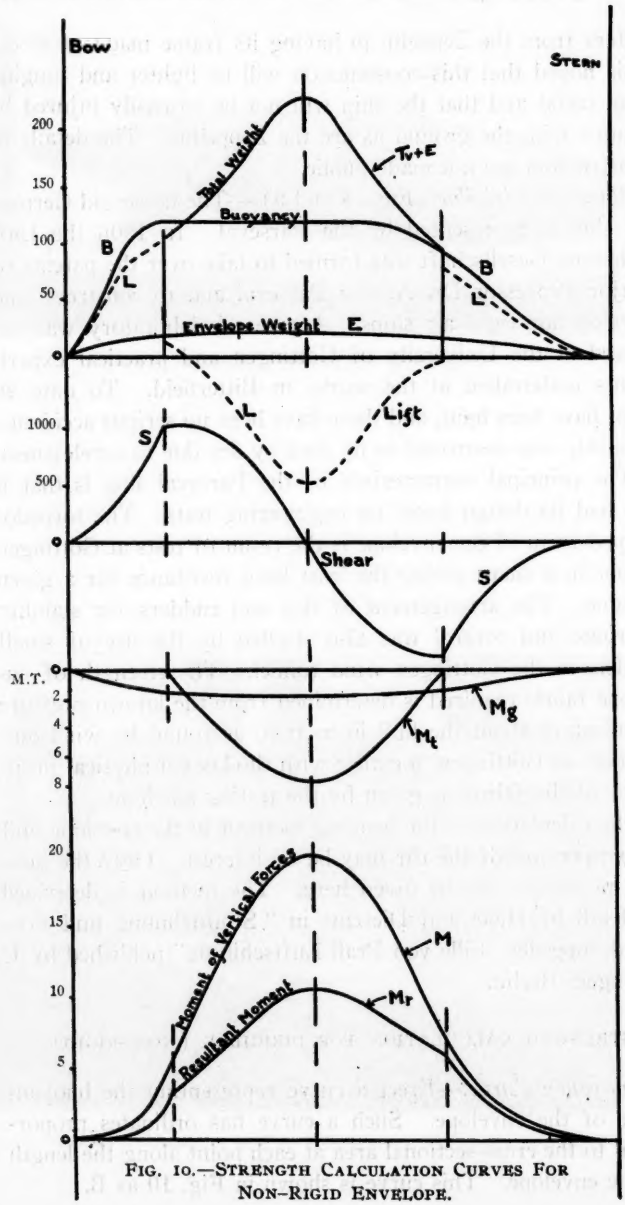


FIG. 10.—STRENGTH CALCULATION CURVES FOR NON-RIGID ENVELOPE.

Envelope Weight.—Erect a curve E representing the weight of the envelope with all attachments, such as fins and rudders.

Car-Weight Curve.—The car is suspended from the belly-band attached to the envelope by a system of rigging, and its weight is distributed among the individual ropes in a manner that can be estimated for any given inclination of the fore-and-aft axis of the ship. Suppose, in Fig. 11, the ropes each

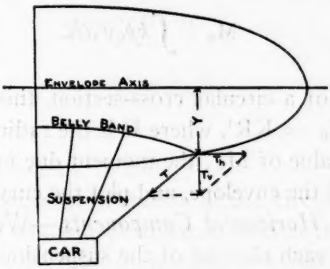


FIG. 11.

have a different tension T. There is then a horizontal compotent T_h and a vertical component T_v for each such rope of the suspension. Estimate the value of T_v for each rope and construct a curve superposed above the curve of envelope weight. The resultant represents total weight, $E + T_v$.

Load Curve.—The difference between the total weight curve and the total buoyancy curve is the load curve L, whose total area is zero, but which lies both above and below the axis.

Shear Curve.—The integral of the load curve L, by a well-known principle in applied mechanics, represents the shearing force at any section. Such a curve is drawn at S.

Bending-Moment Curve.—The integral of the shearing-force curve is the curve of bending moments M. The nature of this bending moment is to cause the ends to be raised, and we represent it as a positive bending moment. This is the moment due to the vertical forces. In addition to this moment we must superpose the moments due to horizontal forces.

Gas-Pressure-Moment Curve.—Over a cross-section of the envelope the pressure difference at the top is greater than that

at the bottom, due to the difference in weight of a column of gas and an equivalent column of air of the same height. If the pressure difference at the level of the axis of the envelope is p_o, the pressure difference at a distance y above the axis is $kyp_o + p_o$, or an excess of kyp_o. The moment about the center of such a force on an element dA of the cross-section is $d\mathrm{M} = kyp_o d\mathrm{A}.y$, and integrated over the cross-section.

$$\mathrm{M_g} = \int kp_o y^2 d\mathrm{A}.$$

In the case of a circular cross-section, this integral reduces to the form $\mathrm{M_g} = \mathrm{KR}^4$, where R is the radius. We may now calculate the value of $\mathrm{M_g}$, the moment due to gas pressure for each section of the envelope, and plot the curve $\mathrm{M_g}$ of Fig. 10.

Moment of Horizontal Components.—We have seen that the force T in each element of the suspension has a horizontal component $\mathrm{T_h}$. The moment of this force about the center of the envelope is $y\mathrm{T_h}$, where y is the vertical distance of the point of attachment of the rope below the center line of the envelope. By calculating $y\mathrm{T_h}$ for each rope of the suspension, we can plot the curve $\mathrm{M_t}$ representing the bending moment due to the horizontal forces acting in the suspension.

The moments due to the above and to difference in gas pressure tend to lower the ends of the envelope, and, according to convention, are negative moments and should be laid off below the axis of the plot.

The difference between the ordinates of a curve representing $\mathrm{M_g} + \mathrm{M_t}$ and the curve of moments M gives a curve of resultant moments $\mathrm{M_r}$. This curve represents the actual bending moment in the envelope at every point. It is important to adjust the design so that this curve shall be as nearly uniform as possible. A large hump in the middle of it represents a high bending moment at the midship section.

The midship section is stressed by the internal gas pressure p according to the well-known boiler formula:

$$f_g = \frac{\pi r^2 p}{2\pi r} = \frac{rp}{2},$$

where

f_g = pounds tension per foot circumference.
r = radius in feet.
p = pressure above atmospheric in pounds per square foot.

The tension on the bottom of the envelope due to the bending moment M_r is represented by:

$$f_m = \frac{M_r R}{I},$$

where

R = radius of section in feet.
$I = \pi R^3$ the moment of inertia of the circumference.
M_r = resultant moment at midship section in pounds-feet.
f_m = stress in envelope in pounds per foot run at top and bottom of section.

The total stress in the envelope at the bottom of the midship section is a tension.

$$t = f_g + f_m$$

At the top of the envelope at the midship section the force f_m is a compression. The resultant tension is here:

$$t = f_g - f_m$$

In a non-rigid envelope the fabric is obviously unable to take a compressive force unless the internal gas pressure be sufficient to create a tension f_g superior to f_m.

The strength of the envelope is calculated from the most stressed portion, where $t = f_g + f_m$. The calculation is repeated for various inclinations of the axis of the envelope.

The following is a general description of the Parseval features (see Fig. 12):

FIG. 12.—PARSEVAL

Type	(Projected) Military air-ship.	(Projected) Passenger air-ship.	Military air-ship.	Passenger air-ship.
Volume	22,000 cb.m.	22,000 cb. m.	16,000 cb. m.	16,000 cb. m.
Length	160 m.	160 m.	137 m.	137 m.
Height	24 m.	24 m.	24 m.	23.5 m.
Diameter of envelope, max.	16.5 m.	16.5 m.	15.5 m.	15.5 m.
Motors	4 of 180–200 H. P.	4 of 180–200 H. P.	4 of 180–200 H. P.	3 of 180–200 H. P.
Propellers	2 pair four-bladed	2 pair four-bladed	2 four-bladed	2 four-bladed
Bulkheads	2	2	1	1
Cars	2	2 and 1 cabin	1	1
Maximum speed, in meters second:				
(*a*) with 4 motors	23	23	22–23	.....
(*b*) with 3 motors	20–21	20–21	20	21
(*c*) with 2 motors	17–18	17–18	17–18	18
(*d*) with 1 motor	.....	.....	.....	.....
Useful lift	8,000 kg. for 15° C. and 760 mm. barometer	7,700 kg. for 15° C. and 760 mm. barometer	6,300 kg. for 15° C. and 760 mm. barometer	7,200 kg. for 15° C. and 760 mm. barometer
Radius hours:				
(*a*) with 4 motors	26.5	20	20	.....
(*b*) with 3 motors	35	27	27	20
(*c*) with 2 motors	53	40	40	30
(*d*) with 1 motor	.....	.....	.....	.....
Radius kilometers (tank fuel only):				
(*a*) with 4 motors	2,200 km.	1,650 km.	1,650 km.	.....
(*b*) with 3 motors	2,600 km.	2,000 km.	2,000 km.	1,500 km.
(*c*) with 2 motors	3,300 km.	2,500 km.	2,500 km.	2,000 km.
(*d*) with 1 motor	.....	.....	.....	.....
Maximum altitude	2,500 m.	2,500 m.	3,000 m.	3,000 m.
Distribution of useful lift:				
Crew	1,200 kg. (15)	640 kg. (8)	720 kg. (9)	640 kg. (8)
Fuel	3,600 kg.	3,600 kg.	3,600 kg.	2,700 kg.
Radio and cabinet	250 kg.	250 kg.	250 kg.	250 kg.
Armament	500 kg.	.....	500 kg.	.....
Equipment, searchlight, etc.	140 kg.	200 kg.	140 kg.	140 kg.
Ballast and passengers	2,310 kg.	3,000 kg.	1,100 kg.	3,470 kg.

AIR SHIPS.

Military air-ship.	Military air-ship.	Military air-ship.	Military air-ship.	Military air-ship.	Altitude ship.
15,000 cb. m.	10,000 cb. m.	9,300 cb. m.	7,400 cb. m.	2,400 cb. m.	10,500 cb. m.
125 m.	ca. 95 m.	95 m.	86 m.	53 m.	90 m.
24 m.	23 m.	23 m.	22 m.	15 m.	26 m.
16 m.	15 m.	14.5 m.	13.5 m.	9.5 m.	16 m.
4 of 180–200 H. P.	2 of 180–200 H. P.	3 of 180–200 H. P.	2 of 180 H. P.	1 of 120 H. P.	2 of 90 H. P.
2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed
1	.....	.....	.....	.....	.....
1	1	1	1	1	1
23	.....	.....	.....	.....	.....
20–21	.....	22.5	.....	.....	.....
17–18	19	18.5	21	.....	15
.....	.....	.....	.....	17	.....
5,700 kg. for 15° C. and 760 mm. barometer	3,000 kg. for 15° C. and 760 mm. barometer	3,200 kg. for 15° C. and 760 mm. barometer	2,550 kg. for 15° C. and 760 mm. barometer	800 kg. for 15° C. and 760 mm. barometer	3,000 kg. for 15° C. and 760 mm. barometer
20	.....	.....	.....	.....	.....
27	.....	10	.....	.....	.....
40	15	13.5	10	.....	20
.....	.....	.....	.....	8	.....
1,650 km.	.....	.....	.....	.....	.....
2,000 km.	.....	810 km.	.....	.....	.....
2,500 km.	1,000 km.	900 km.	756 km.	.....	1,100 km.
.....	.....	.....	.....	490 km.	.....
2,500 m.	2,000 m.	2,000 m.	2,000 m.	1,100 m.	3,800 m.
560 kg. (7)	560 kg. (7)	480 kg. (6)	400 kg. (5)	300 kg. (4)	560 kg. (7)
3,600 kg.	1,350 kg.	1,350 kg.	900 kg.	300 kg.	900 kg.
250 kg.	250 kg.	250 kg.	250 kg.	.....	250 kg.
50 kg.	150 kg.	200 kg.	200 kg.	.....	50 kg.
200 kg.	.....	.....	.....	.....	150 kg.
1,040 kg.	690 kg.	920 kg.	840 kg.	200 kg.	1,090 kg.

Envelope.—The envelope is made to the plans of the Parseval designers by the firm of A. Riedinger, Augsburg. This is one of the oldest balloon factories in the world, and has developed great skill in cutting and working rubberized fabrics. The material is purchased and tested at the Parseval works, whose specifications must be followed. Riedinger further tests it for gas tightness and stretching, in order to guarantee permanence of form. The fabric is cut in strips by the aid of paper patterns from which an empirical allowance for stretch has been deducted. The allowance for stretch is based on tests of samples and on experience with previous envelopes. Fabric of ultimate strength of one ton per linear meter is used for small envelopes, and fabric of strength two tons per meter for envelopes over 8,000 cubic meters in volume. Over the propellers the fabric is doubled to protect the envelope from splinters in case of propeller rupture.

The nose is stiffened to stand the wind pressure at high speeds, and to permit mooring to a mast in the open.

Two ripping seams are provided. In case of a forced landing in a storm, the pilot can instantly deflate the envelope by pulling the rip cords. This feature is common to all non-rigid ships and is a great advantage of that type.

The internal gas pressure is from 20 to 30 millimeters of water.

The loss of gas through the fabric is about 1 per cent. of the total volume per 24 hours.

The envelope is fitted with a lower gas valve, spring loaded or opened at the will of the pilot. There is also an upper gas valve for use in case the lower one sticks. Normally only the lower valve is opened, as it releases the heavy and impure gas.

Ballonets.—Inside the envelope are two air sacs or ballonets of total volume about one-third of the envelope. Air is admitted to one or the other ballonet by means of a three-way valve in the trunk leading to the blower in the car. The size of the trunk and capacity of the blower are calculated to supply air to the ballonets at a sufficient rate to permit a given rate of descent without loss of form.

Suspension.—The car hangs from the envelope on six steel cables attached at the top to crow's feet of flax rope (electrical insulation of the envelope from the car) which toggle into a belly-band or fold of heavy canvas sewed to the bottom of the envelope. The load on the belly-band is then carried by belts of canvas passing over the top of the envelope. Each belt is enclosed in a pocket of fabric to prevent longitudinal motion, but is otherwise free to slip and adjust the load equally on the two sides of the car. Fore-and-aft motion of the car is prevented by fore-and-aft wire stays. Each of the two forward stays passes under rollers on the car and becomes an after stay. In the center of the horizontal portion is fitted a rack held by a pinion. By turning this pinion the car can be hauled forward or aft through a distance of about 2 feet 6 inches. This displacement of the center of gravity gives a powerful steering couple to be used when the ship has not speed enough to make the horizontal rudders effective. The longitudinal equilibrium may also be adjusted without discharging or shifting ballast.

Car.—The car is built of steel tubing in a substantial manner to withstand shock of landing. It can be taken apart for shipment. A sound-proof cabinet is fitted for the wireless telegraph operator. The framing of the car is completely enclosed by sheet metal or fabric. The pilot stands behind celluloid windows. In the ships under construction the car will be watertight to serve as a float in landing on water.

Motors.—Two Maybach motors are mounted to operate in tandem on the same shaft. The car is made elastic to avoid use of springs, and to preserve shaft alignment several cardan joints are provided. An effective muffler and a jacking device for starting the motors are usually fitted.

Propellers.—Two steel plate propellers, four-bladed, with reversing pitch, or two walnut propellers, two-bladed, with reversing clutch, are mounted on side brackets and driven by gearing from one or both motors.

Wireless.—The radius of the Huth wireless set is about 300 kilometers. Total weight, 250 kilograms.

Searchlight.—A searchlight lighted by current from a dynamo driven by the motor shaft is good to distinguish large objects on a dark night from a height of 1,000 feet.

Instruments.—Engine telegraph from pilot, barograph, barometer, manometer for each ballonet, two manometers for gas, one aneroid pressure gage for gas, one water gage for cooling water, one oil gage, one fuel gage, one fire extinguisher, one surgeon's box.

Certain ships have also been fitted with a machine gun in the bow, and a bomb projector below the floor of the car.

Crew.—One chief pilot to maintain level, one pilot to maintain course, three machinists, one wireless operator, relief crew as required.

ENGLISH DIRIGIBLES.

English experience with air ships was at first disastrous. The great rigid dirigible *Mayfly,* built by Vickers, had a framework of aluminum alloy bars as in the Zeppelins, but the longitudinal strength was not sufficient and the ship's back was broken in the first attempt to launch her in 1911. The French Lebaudy air ship *Morning Post,* a semi-rigid, was lost the same year when she became entangled among telegraph wires and trees along a road near Farnborough. The cause of the accident was a wind slightly too great for the ship to maneuver against.

From 1909 to 1913 the Royal Air-craft Factory built five small non-rigid air ships of an experimental nature, ranging in volume from 600 to 6,000 cubic meters. The last completed, the *Eta,* of 6,000 cubic meters, has made some very good flights. Its design is based on experience with the previous British air ships and upon the purchased French and German dirigibles. In 1913 one Astra-Torrés 6,500-meter ship and one Parseval 8,800-meter ship were purchased. It is reported that these orders have been followed by further orders to these foreign factories. The great shipbuilding and armament firm of Vickers, Ltd., has secured the rights to build the Parseval air ship in England, and Armstrong, Whitworth & Co. have secured the rights for an Italian ship, the

Forlanini. It is understood that three Forlanini semi-rigid dirigibles are to be acquired by the Admiralty. The sudden expansion in dirigibles is due to the vigorous policy of the Admiralty in its desire to create an aerial fleet.

The following features of the *Eta,* built by the Royal Aircraft Factory, may be of interest:

Envelope.—The envelope is made of "Continental" double diagonal rubberized fabric, treated with chrome yellow on the outside to protect the rubber from sunlight. Seams are gummed with rubber cement and stitched on a two-needle sewing machine by women especially skilled in this work. The form of the envelope is the result of tests in the wind tunnel at the National Physical Laboratory.

Suspension of the car is the ordinary French type, by means of steel cables and crow's feet of flax toggled to a canvas belly-band.

Car is of steel tubing covered with fabric. No springs are fitted under the motors. The car is readily taken down for transport over seas.

Power plant consists of two 150-horsepower Salmson (French) motors driving through clutches and bevel gearing two four-bladed wooden propellers. Provision is made for swivelling the propeller axes in a vertical plane as in the latest Astra ships.

Crew is composed of one officer in charge, observer; one quartermaster to maintain altitude; one quartermaster to maintain course; three machinists.

For a landing, the assistance of about 40 men is required in windy weather, and provision is made for mooring by the nose to a mast in the center of an open space.

Instruments.—One revolution counter, one barograph, one aneroid gas-pressure gage, two gas-pressure manometers, two ballonet-pressure manometers, one liquid compass.

Ballast.—In canvas water bags in car.

It should be stated here that the procedure of mooring to a mast was originated in England at the Royal Air-craft Factory.

ITALIAN DIRIGIBLES.

The Italian Government has three classes of dirigibles: the P class (small, of less than 5,000 cubic meters), the M class (medium size, between 8,000 and 12,000 cubic meters), and (under construction) the G class (20,000 cubic meters volume). At the present time Italy has 5 P class and 5 M class, with 2 G class building.

The small P class ships have a speed of 50 kilometers per hour on a volume of 4,500 meters, and are not considered suitable for war scouting. They are valuable for training purposes, however.

The M class is represented by five semi-rigid ships of 12,000 meters, designed by Captains Crocco and Ricaldoni. The keel is a rigid structure built into the envelope. The car is a completely enclosed boat provided with windows. The crew are thus protected from the weather. A speed of 70 kilometers, or 44 miles per hour, is given by two 250-horsepower motors. Usually Italian motors are used: Fiat, Isotta, etc. Radius of action is 1,000 kilometers, or a maximum flight of 35 hours at reduced power at an altitude of 1,000 meters.

The "Forlanini" semi-rigid ships have recently been very successful. The Italian army has one ship of 12,000 meters, and is reported to have under construction one G1 or "Forlanini" of 20,000 cubic meters, speed 72 kilometers, 800 horsepower. A larger ship is projected of volume 24,000 cubic meters and speed 100 kilometers on 1,000 horsepower. The British Admiralty is reported to have recently ordered three "Forlanini" ships, one to be built in England and two to be built in Italy.

The "Forlanini" type is distinguished by a completely enclosed car which forms part of a long, rigid keel extending the entire length of the envelope. The keel is crescent-shaped longitudinally and square-sectioned transversely. The ends of the keel are tied together by a steel cable running through the envelope.

The envelope is in two parts, meeting along the top center

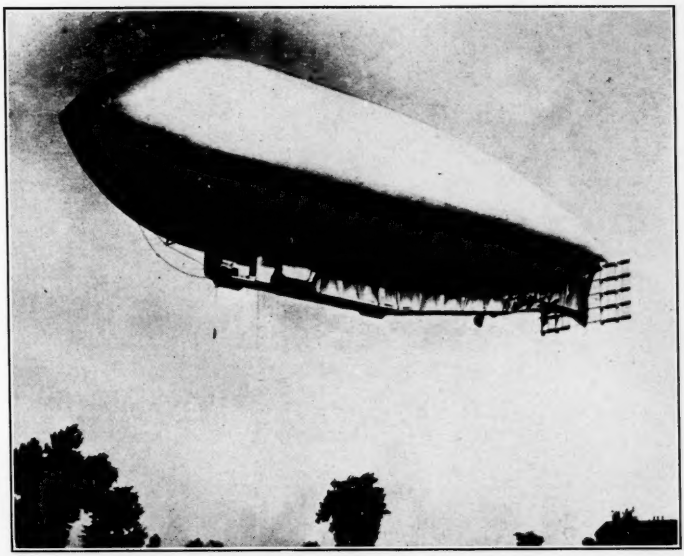


FIG. 13.—FORLANINI SEMI-RIGID "CITY OF MILAN."

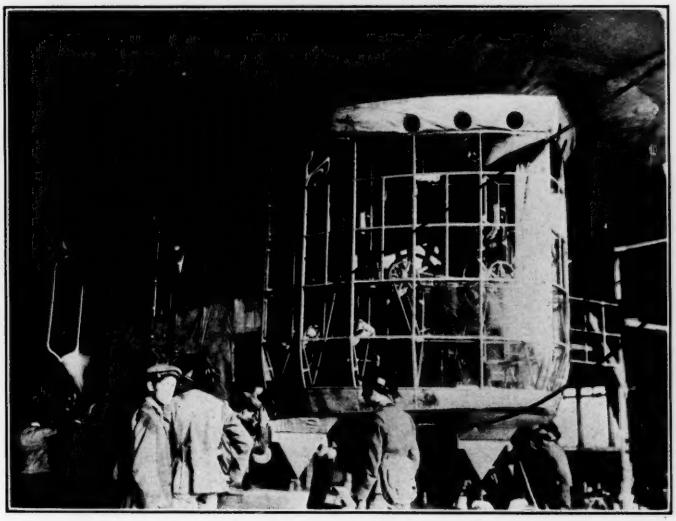


FIG. 14.—CAR OF FORLANINI "CITY OF MILAN."

line. The inner envelope is made up of 14 compartments. The inner and outer envelopes are kept apart by ballonets. The British ships are reported to displace about 12,000 cubic meters, length 72 meters, diameter 8 meters, two three-blade propellers of diameter 4.2 meters, maximum speed 44 miles per hour, on two Fraschini motors of 100 horsepower each.

By virtue of the semi-rigid construction the ordinary suspension of the car from the envelope is avoided and the car placed inside the keel. Head resistance is, of course, reduced, and the power required for a given speed still more reduced.

The Italian army has at present one German Parseval non-rigid air ship of 10,000 cubic meters and another ordered.

DISCUSSION OF TYPES OF DIRIGIBLES.

The three types of dirigibles—rigid, semi-rigid and non-rigid—in all probability will continue to be built, as each possesses peculiar advantages.

The rigid Zeppelin type is considered to possess the following advantages over the other types:

(1) Possibility of constructing of enormous size with correspondingly great speed, radius of action, and weight-carrying ability.

(2) Cellular subdivision of gas bags, giving less danger from ripping or bursting of envelope. In a rigid ship one gas bag may be pierced by a shot without loss of more than one-twentieth of the lift.

(3) Preservation of longitudinal strength independent of gas pressure.

(4) Reduction of head resistance due to suppression of external suspension to car.

(5) Ability to descend rapidly, due to (3).

(6) Ability to go for long periods of time without material loss of gas, due to the fact that gas bags may be made of gold-beater's skin.

(7) Long life, because outer covering of envelope is not rubberized or gastight.

(8) Form does not change, due to stretch of fabric.

(9) Less severe temperature expansion of gas in passing from sunlight to shade. The outer envelope and dead-air space insulate the internal gas bags.

(10) Gas pressure is only slightly above atmospheric when at low altitudes, and the flow of gas from a shot hole in a Zeppelin has about one-half the velocity of flow from a similar hole in a non-rigid envelope at the same altitude. Also in the former case the flow of gas ceases when the gas below the level of the hole has escaped.

On the other hand, the large rigid air ships are very costly, and require still more expensive sheds to house them. On the ground they are very unwieldy and require two or three hundred men to hold them against a moderate breeze. There is great danger of straining the rigid frame in a bad landing—an injury that destroys the usefulness of the ship. The rigid ship cannot be transported by rail or steamer.

The disadvantages of the rigid type are the corresponding advantages of the non-rigid type. For example, the peculiar advantages of the non-rigid may be enumerated as follows:

(1) They are less costly for the same service.

(2) Due to saving of weight of rigid frame, a non-rigid ship may be designed to have the same lifting power as the rigid ship, but with a 20 per cent. smaller envelope volume.

(3) The housing is less costly, due to smaller size. At the same time, several ships with envelope deflated may be stowed in a single shed.

(4) The non-rigid ship is not injured so easily on the ground. Its longitudinal strength is given by gas pressure, and is not affected by a bad landing.

(5) The smaller non-rigid ships can be moored to a mast in the open.

(6) The non-rigid can instantly deflate its envelope, if it has to land in a strong wind, by pulling the ripping panel.

(7) About 50 men can hold a 10,000 cubic meter non-rigid in a moderate breeze.

(8) The non-rigid ships can be easily deflated, taken apart,

and shipped in several packages by motor truck, railroad or steamer. This is a great advantage for naval purposes.

(9) Injuries to the envelope of the non-rigid ship are easy to repair, and, though the envelope may last but three years, it can be replaced at a cost of less than $2 per cubic meter.

Like all compromises, the semi-rigid dirigible, in an effort to combine some advantages, has combined some disadvantages of both the rigid and non-rigid systems. For example, the semi-rigid dirigible has advantages to some extent of the non-rigid type as enumerated above in paragraphs 1, 2, 3, 5, 6, 7 and 9, and advantages 1, 3, 4, 5, 8, enumerated for the rigid type. On the other hand, the greatest advantage of the non-rigid type—its portability—it does not possess. The long keel is heavy, easily damaged and cumbersome. It combines the vulnerability to puncture of the non-rigid ship with the unwieldiness of the rigid ship. Furthermore, the placing of the gasoline motors in a car built in the keel immediately below the envelope is a fire risk not to be ignored.*

It is probable that difficulties of construction render the rigid type desirable for ships of more than 16,000 cubic meters volume. Below this size the non-rigid type appears to have the advantage. The semi-rigid system has been most satisfactory when applied to ships of volume near 16,000 cubic meters.

Air ships of any type are in the position of small boats on the sea. It is impossible to navigate in a storm. It is true that a powerful high-speed Zeppelin could make headway against a wind that a less powerful non-rigid ship could not cope with. This advantage is not, however, a practical one, for the apparent advantage of the great rigid ship exists only while in the air. The larger ships can neither leave their sheds nor enter them when a wind is blowing that does not present insuperable difficulties for the non-rigid ships. A wind of 15 miles per hour is about the upper limit for the safe

*The Italian semi-rigid Forlanini dirigible *Citta di Milano* was destroyed, April 9, 1914, on the ground, by explosion of hydrogen and subsequent fire. Fifty persons were injured. Cause unknown.

handling of a Zeppelin on the ground, where this wind must be taken broadside on (across the mouth of the shed).

A form of rotating shed mounted on a turntable has been built in Germany and should be an advantage in case of unfavorable wind. The construction is very costly, however.

ACCIDENTS TO DIRIGIBLES.

Disputed points in general design and possible improvements to be desired are best considered in the light of the accidents that have occurred. Unfortunately, the development of a new kind of transportation is inevitably accompanied by many accidents, and very often our attention is drawn more forcibly to the accidents than to the successful trips. This statement applies to dirigibles, submarines, subways, great passenger steamers and 18-hour trains. Accidents are horrible enough in themselves, and are, furthermore, unnecessary and useless if some lesson is not taught.

Considering first the non-rigid air ship, we find that in the first Santos-Dumont ship the envelope collapsed in descending, due to the fact that blower and ballonet were not powerful enough to keep the gas pressure constant. The second Santos-Dumont non-rigid had its envelope collapse when it ascended in a rain storm, due to contraction of gas with cold. Here again the ballonet was not powerful enough. The conclusion from these accidents is that a powerful blower and large ballonet are absolutely essential to the safe operation of a non-rigid dirigible. However, in the cases cited the aeronaut was merely forced to descend abruptly. He was in no way injured.

In the Santos-Dumont 6 of 1902 the gas all ran to one end of the envelope, and lifted it up so that the controls could not bring the ship down to an even keel. There was danger of the suspension fouling the propeller and the bag bursting. This is a disadvantage of a large non-rigid ship. In the Santos-Dumont 7 silk non-gastight partitions proved a remedy. In the large non-rigid dirigibles projected for 1914, both in France and Germany, it is proposed to fit partitions

in the envelope. There is danger of bursting in case a wave motion is set up, due to the impact of gas on the ends.

The Santos-Dumont 7 of 1902 was directionally unstable, due to its form of envelope. The same trouble has been had with other ships. The remedy lies in placing the center of side resistance abaft the center of gravity, as in the ordinary weather-cock or feathered arrow.

The *Republique,* 1909, was destroyed when a propeller burst and cut the envelope. The cut quickly extended to a great tear, and the ship crashed to the ground. Ships since that day have employed a fabric that will not tear easily if punctured. Usually the fabric is made up of two or three layers of cloth, with intervening layers of rubber, the whole pressed together and vulcanized. The warp and weft of fabric in each layer are diagonal to the threads of the other layers. This is called diagonal doubling. Such fabric does not tear readily. An extra patch is placed on the envelope over the propellers to protect it from splinters.

A great many ships of all types have been lost by attempting to navigate in too high a wind. Examples are:

1901—Santos-Dumont 5, landed in a tree.

1902—Lebaudy, landed in a forest.

1907—Lebaudy, broke away from 200 men holding it and floated out to sea.

1909—Clement Bayard, broke away from 40 men holding it and blew into the Seine.

1911—*Morning Post,* lost control and became entangled among telegraph wires and poles.

1913—Zeppelin L2 caught in cloudburst over North Sea and pounded into water, where the high sea broke her back.

The obvious conclusion from such experience is that an air ship should have a speed sufficient to cope with the winds to be expected in her district. It is estimated that near Paris a ship capable of a speed of 45 miles per hour can maneuver 234 days in the year, allowing for 75 days of fog, snow or rain.

The speed of 45 miles per hour is figured as 8 miles per

hour greater than the wind. It is usually considered that for safe handling a dirigible's speed should be at least 8 miles per hour greater than that of the wind. A speed of 45 miles per hour in France is the minimum for general military utility. It is possible that in the southern part of the United States, and near Cuba and Panama, a ship of 45 miles per hour maximum speed could navigate over 300 days in the year. In any case the speed of our ships must be based on probable meteorological conditions. There is no ship yet designed to navigate in a tempest. A speed between 50 and 60 miles per hour is, however, practicable.

At the present time hydrogen lifting two and a half pounds per cubic meter is the only gas used for air ships. Coal gas gives only about half this lift. Also, gasoline or similar volatile distillates is the only fuel used for internal-combustion motors. Unfortunately, both gasoline and hydrogen form explosive mixtures with air, and the motor has an ignition system and a hot exhaust pipe and muffler. The combination is a bad fire risk, and many ships have been lost by fire. In the past year or two the installation of wireless telegraphy and its high potential sending current is another source of danger. The car is in the non-rigid ships electrically insulated from the envelope.

The following ships lost by fire give an indication of the importance of the fire risk in design:

1879—Wölfert's rigid ship, a gasoline fire in the car ignited the hydrogen in the envelope.

1908—Zeppelin 3: torn by wind from moorings and blown aloft, where it caught fire and exploded.

1912—Zeppelin 10: burned in its shed at Düsseldorf.

1911—Parseval 5: burned in its shed at Münden.

1913—Zeppelin L 2: fire in the forward car ignited hydrogen in the envelope, where it exploded with great violence. It is reported that in this new ship an effort at high speed was to be made by reducing head resistance in every way. The cars were placed close under the envelope, and a connecting passage from forward to after car built inside the envelope.

Leakage of gas into this passage (*Laufgang*), which was not ventilated, probably found its way to the forward car. A wind shield here made an eddy or suction behind it in the car, and air and gas from the *Laufgang* could easily have been sucked in. A flooded carburetor, red-hot exhaust pipes, or other cause could then have ignited the gas. In any case, the ship was completely destroyed in the air by the force of the explosion.

It seems that the cars containing the gasoline, motors, guns, wireless sending station and other sources of fire should be kept well away from the envelope. In the rigid and semi-rigid ships the cars are very close to the envelope. In the non-rigid ships difficulties of suspension require the car to be hung on cables some distance below the envelope. So far as fire is concerned, the non-rigid ships seem safer, though the low car causes an increase of head resistance. The relief valves on the envelope are often placed at the bottom so as to discharge the heavier and more impure gas. In the non-rigid ships this may not be a source of danger, as hydrogen rises as soon as released and should not reach the car. The placing of gas valves should, however, be very carefully considered with reference to the suspension of the car.

It has been suggested that certain explosions of balloons in which no fire was carried may be due to discharge of atmospheric electricity. Thus a balloon on touching the ground may be charged with static electricity of potential equal to that of the upper air. Unless this potential be lost in descending, it may easily be possible for an electrical discharge to take place between a part of the balloon touching the ground and some metal part, such as a gas valve. Gas valves are largely made of fiber, in view of this danger, and in dirigibles all metal parts are electrically connected. The envelope of most non-rigid ships has no metal parts, and is insulated from the car by crow's feet of flax rope.

The great difficulty in design of the rigid-type ships is to get sufficient stiffness with small weight.

The following accidents represent the loss of several fortunes:

1897—Schwartz rigid: back broke from jar in striking ground.

1900—Zeppelin I: frame bent on first trip.

1900—Zeppelin II: frame broken by pounding on ground when anchored in the open.

1900—Zeppelin III: frame broken when jammed in door of shed.

1901—Zeppelin VIII: frame broken when jammed in door of shed.

1911—Mayfly, Vickers: back broken when launched.

The rigid hull of such ships is a most delicate structure and renders the rigid air ship most vulnerable when improperly handled. The importance of a highly-trained personnel is apparent.

Due to the fact that the right hull cannot be deflated, the rigid-type ships are only useful where adequate housing facilities are provided. The reliability of the motor is a vital factor in all dirigible operation. The *Zeppelin II* in 1900 was forced to land in an open field by motor stoppage. The ship was anchored to stakes driven in the ground, but a wind came up and pounded the vessel against the ground until the frame was broken. A non-rigid ship would have deflated the envelope in such a case. In 1901 motor trouble forced the non-rigid *Santos-Dumont 5* to land on a roof. No damge was done, however. In modern dirigibles considerable weight is sacrificed to reliability in the design of the power plant. The motors are water-cooled, of moderate piston speed and of substantial construction. Duplicate ignition systems are provided, and forced lubrication. It is becoming the practice to enclose the motors completely in order to protect them from rain and snow. Self-starting devices are frequently fitted, but in any case hand cranking or jacking arrangements are installed. Gages are fitted to give warning of a low supply of fuel, oil or water.

For any air ship there is a limit to the wind which she can

be expected to cope with, and it is obviously of great interest to have a trustworthy weather forecast before undertaking a voyage of any duration. In Europe the greater part of the violent storms come from the Atlantic, and their approach cannot always be known. The loss of the naval *Zeppelin L1* over the North Sea in 1913 was primarily due to a violent and sudden rain squall of whose coming the weather forecasts gave no warning. In 1910 the Zeppelin *Deutschland* was caught in a strong rising current of air and the pilot was unable to prevent her being carried to a great height. The gas was chilled and contracted at the high altitude, and probably the pilot had opened his valves to check the ascent. In any case, the ship suddenly lost her buoyancy and dropped into a forest.

It is thus clear that it is not alone necessary that for safe dirigible operation the surface winds be not violent. The pilot should have assurance that disturbances in general meteorological conditions are not approaching. It has been found that pilot or sounding balloons, sent up before a voyage in a dirigible is started, may give valuable warning of unsettled conditions in the upper atmosphere. The pilot should have reports from observation stations in the vicinity, as well as a weather map showing the general barometric pressure distribution. During a voyage the barometer must be watched and its indications given careful consideration. In ships fitted with wireless hourly reports may be received from the home station. Safety in dirigible operation, questions of design not considered, must always depend upon the judgment of a weather-wise pilot and upon the trustworthy meteorological data that are supplied him.

The above discussion of accidents has been undertaken here in order to emphasize the vital importance of:

(1) Sufficient blower power and ballonet volume for non-rigid ships.

(2) Partitions in long non-rigid envelopes to prevent shifting of gas.

(3) Sufficient fin area abaft the center of gravity to give directional stability.

(4) Provision against envelope of a non-rigid ship ripping when punctured.

(5) Sufficient speed to cope with winds to be expected in the district.

(6) Every possible precaution against fire.

(7) Electrical connection of metal parts.

(8) Adequate housing for rigid ships.

(9) Reliable motors.

(10) Correct weather forecasts.

(11) Experienced personnel.

In nearly all the accidents cited there is some one cause that might be prevented in subsequent ships. In this way improvements in design and operation have been brought about that now make a dirigible a fairly safe and useful method of transportation. The press naturally describes an accident in great detail, but, now that successful aerial voyages are of such frequent occurrence, mention of such performances is only made when the breaking of a record or the presence of distinguished persons gives news value to the report. For example, the three Zeppelins—*Hansa, Sachsen* and *Viktoria Luise*—during the past summer made passenger trips every fair day of from two to six hours' duration without a single accident. Long-distance trips were also made between various German cities, and one to Copenhagen.

COMMERCIAL USE OF DIRIGIBLES.

Due to high cost of maintenance, some danger, and dependence upon weather conditions, air ships have not yet been proved of great commercial value. It is true that thousands of passengers have been carried by the Zeppelins of the Delag Company in Germany, but this company has been heavily subsidized in order that its operation should not show a loss. The entertainment of tourists is a legitimate commercial enterprise, but the air ship cannot be considered of real service to

FIG. 15.—NEUHAUSEN FROM A HEIGHT OF 3,000 FEET.

FIG. 16.—NEUHAUSEN FROM A HEIGHT OF 3,000 FEET. TELEPHOTO FROM DIRIGIBLE.

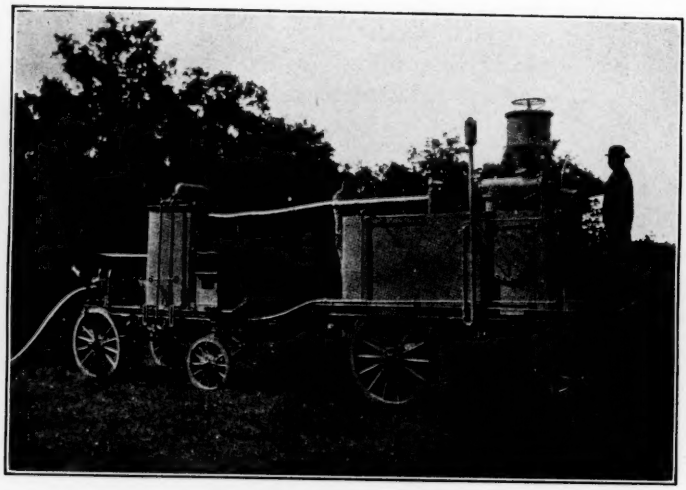


FIG. 17.—PORTABLE HYDROGEN GENERATOR.

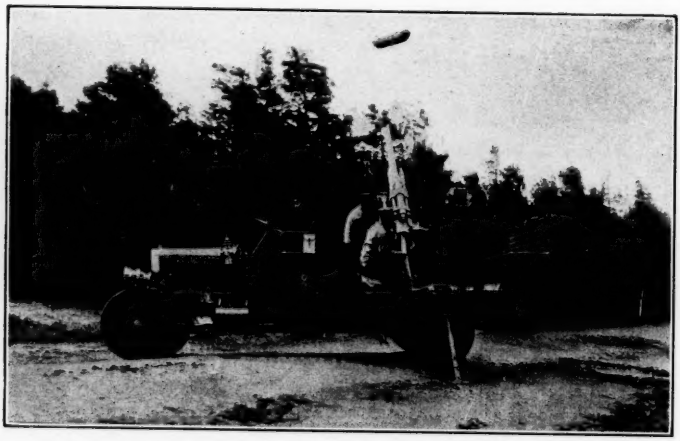


FIG. 18.—GUN FOR FIRING AT AIR-CRAFT.

commerce and industry until it can maintain regular schedules between fixed points that men's affairs require them to visit. The passenger-carrying business so far has been of the nature of sight-seeing trips up the Rhine or around and over Berlin. There is no more delightful way to see the country. Provided with a good map, a passenger can become acquainted with a great area of country in a few hours' time. This facility for observation leads at once to the consideration of the use of air ships in time of war.

MILITARY USE OF DIRIGIBLES (FIGS. 15, 16, 17, 18).

The dirigible operating in clear weather at an altitude of some 5,000 feet is fairly safe from gun fire and yet not too high for a trained observer to detect the movements of large forces on the ground, general features of fortifications, number and type of ships in a harbor, presence or absence of bridges and railroad tracks. The dirigible can stop its motors and float slowly above ground it is desired to observe. The aeroplane cannot perform such service except by circling above a given area, thus reducing its fuel supply and future usefulness. The great test in military operations of the dirigible will be for long-distance reconnoissance. In a country whose probable enemies lie within the radius of action of air craft, dirigibles may be used at or before the opening of hostilities to pass over the enemy's frontier to observe the mobilization of troops, their direction of march and probable destination. A dirigible, unlike the aeroplane, is fitted with wireless telegraph both for sending and receiving messages, and may keep in constant communication with its base. The radius of action in a calm of large rigid air ships may be 2,000 miles, and medium-sized non-rigid ships 1,000 miles. An aeroplane cannot be depended on for more than 400 miles when an observer must be carried in addition to the passenger. A dirigible can save fuel by drifting with the wind, and it is well known that by selecting a suitable elevation a favorable wind can very often be found when the wind on the ground is contrary.

The greatest usefulness of the dirigible will be at night. At the present time aeroplanes cannot be flown at night. The dirigible at night can travel close to the ground without danger from gun fire, and can observe the extent and disposition of camps.

For pure reconnoissance work an army could use large rigid dirigibles for distant scouting to develop the enemy's principal movements preceding the actual meeting. Due to its portability, any expeditions into the interior of an enemy's country or in the colonies would be best served by non-rigid dirigibles. These ships are easily crated for shipment, and can be inflated in the field from bottled hydrogen or a portable gas plant drawn by a motor truck. Large sheds are not necessary, as the ship can be moored in the open to a post in good weather and deflated in a violent storm. In cases where both rigid and non-rigid air ships might be used, the non-rigid ships might observe from a safe altitude the progress of a battle and the effect of artillery fire. Aeroplanes would be used for transportation of staff officers, dispatch duty, and scouting within the limits of the battlefield. The same functions at night would be performed by the non-rigid dirigible.

In case of siege, where the enemy has possession of a great expanse of surrounding country, communication with the besieged forces could be had by means of a dirigible of sufficient radius of action. Its going and coming would be masked by darkness.

The use of dirigibles in modern wars will be greatly restricted by the enemy's aeroplanes, which must be supposed superior both in speed and climbing power. On the other hand, a dirigible will mount several machine guns and, having a steady gun platform, can deliver a much better directed fire than the aeroplane. It is not clear what might be the result of an aerial skirmish between a scouting dirigible and the enemy's aeroplanes. However, a unit of a dirigible fleet is so much more valuable than a whole squadron of aeroplanes that it seems unlikely that a dirigible would seek an encounter. In the case of modern armies, where aeroplanes may be sup-

posed numerous and their pilots ready to take risks, the operations of dirigibles will be, no doubt, chiefly conducted under cover of darkness or in strategic reconnoissance far removed from the field of battle.

A large dirigible can carry over half a ton of bombs or torpedoes. In view of the great target which it presents, and the provisions made in European armies for the attack of dirigibles by shrapnel fire, it is unlikely that it will be attempted to drop bombs on an army in march or upon a fortified place. Furthermore, at night it may not be possible to drop bombs with any chance of hitting a given object. There will be cases, however, where a dirigible may be sent out to destroy a bridge, an enemy's dirigible shed, an arsenal, a canal lock or other large object. The dirigible can make its journey by night, and before dawn, as soon as there is sufficient light, can descend close to its target, drop half a dozen 100-pound gun-cotton torpedoes, and be away before she has been fired on. The surprise is no doubt to play an important part in any offensive operations of dirigibles.

The effect of bombs dropped from aloft in no way compares with that of shells from great guns on account of lack of penetration before explosion. The best that can be expected is a surface explosion and incendiary effect. The moral effect of dropping bombs into an enemy's camp at night must not be ignored. Doubtless, the damage may not be very great, but the effect of hourly explosions would certainly be depressing. A camp offers a large target, and a dirigible might easily hover above it all night above the range of searchlights. Its motors would be stopped or used at low power to hold position. Mufflers can be made as effective as in automobiles.

The rules of civilized warfare probably will not tolerate the dropping of bombs upon an enemy's city, and in case the place is besieged and non-combatants warned to leave it, bombardment by artillery will probably be more effective than dropping bombs from an air ship during the night.

It seems to be the general opinion that the use of dirigibles will be more for reconnoissance than for offensive operations,

but that in special cases offensive operations promise a chance of success.

NAVAL USE OF DIRIGIBLES.

The large rigid-type dirigible may be of service to a navy whose probable adversaries have dockyards and naval bases within the radius of action of such air ships. The opening of hostilities might be preceded by a dirigible reconnoissance over the enemy's sea coast to observe the disposition of his fleet. A dirigible might easily pass over all of the enemy's great dockyards and naval bases and so ascertain whether the enemy's fleet be concentrated or scattered, the number of ships engaged in coaling, the number of ships in drydock or otherwise out of action. It might well be that such reconnoissance would reveal such a condition of unpreparedness that, without formal declaration, war might be opened by an inferior force with a fair chance of destroying a division of the enemy's fleet before the other units could be mobilized.

For such strategic reconnoissance the great endurance and radius of action required indicate the rigid-type ship as more suitable than the medium-sized non-rigid ship.

After war has been declared, if it be determined that the enemy is to take the offensive with one out of several probable objectives, it will be of vital importance for the defending navy (which we might assume inferior in force) to keep its fleet concentrated and endeavor to engage a portion of the enemy's superior fleet under advantageous conditions. The enemy's tactics might be to send a few ships to make a demonstration at several points and then to throw his main force upon another point which he might expect to find undefended by ships of the defending fleet. If all probable points of attack were patrolled by non-rigid dirigibles it might be possible to determine the enemy's plan of attack and the number and power of the units in each of his subdivisions. The defending fleet could then select its conditions of battle and engage with a part of the enemy with a definite knowledge of his power and of the location of the other division of his fleet.

The number of dirigibles needed for a complete patrol of extensive coastal waters and islands would indicate the use of non-rigid ships whose radius of action is sufficient. This service could also be undertaken by hydro-aeroplanes, but, since the scout is waiting for the enemy to come within, say, 200 miles of a given point, the hydro-aeroplane could hardly afford to proceed to a point 150 miles out to sea, there to circle round until the enemy is sighted. The dirigible can float about with motors almost stopped for a day or more without great loss of fuel.

On the other hand, the enemy with the superior fleet might wish to know the location of the defending fleet in order to seek it out and destroy it or to blockade it in port. If the action were to take place at a great distance from the enemy's base an advanced base near the field of operations would be seized, portable non-rigid air ships set up and inflated, and sent out on definite scouting expeditions.

In general it may be considered that the offensive power of air ships would have little effect upon armored-decked battle-

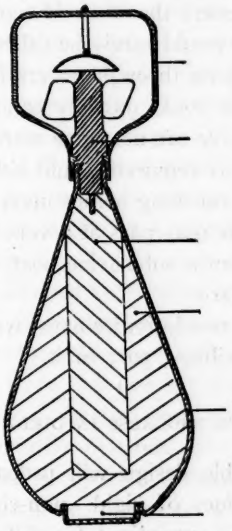


FIG. 19.—DIRIGIBLE TORPEDO.

ships. Bombs and torpedoes (Fig. 19) will burst on the surface of such decks, turret roofs, etc., and do local damage, but probably will not injure any vital parts. A ship is a small target to hit from the altitude of 5,000 feet, which is required by day to be safe from gun fire. At night an air ship may pass low over a ship, but in war time no man-of-war will show lights, and, unless the moon be bright, the dirigible has small chance of finding the ship. It is stated by some pilots that when an air ship is over a steam vessel a red glow is seen down the funnels. A bomb dropped down a funnel would certainly seriously damage the uptakes. It may well be considered prudent to fit gratings over the top of smoke pipes on battleships.

As in the case of military operations, there may be special cases when a dirigible may be required to drop incendiary or high-explosive bombs on dockyards, drydock caissons, vessels building, magazines and workshops. Great damage might be done, but the battle fleet could not in this way be greatly reduced in power.

It seems that the principal function of the dirigible in naval warfare is to supplement the work of scout cruisers, and that its offensive powers would rarely be called upon.

In attempting to pass through waters in which mines have been laid, a dirigible could possibly conduct counter mining operations. A dirigible can also give warning of the presence of submarines, and, if required, could rid a passage of these dangerous craft by launching bombs upon or near them. For this duty the dirigible may pass at a very low altitude, as she has little to fear from a submarine boat, unless the latter be running on the surface.

Dirigibles will not revolutionize naval warfare, but may play an important, if auxiliary, part in it.

FUTURE PROGRESS IN DIRIGIBLES.

Progress in dirigible design will probably continue to be directed along the lines of rigid, non-rigid and semi-rigid types, each type being specialized for different functions.

It does not appear likely that any gas other than hydrogen will be used, but it is not clear that gasoline is the fuel best suited to dirigible motors. The adoption of a less dangerous fuel than gasoline will be a step in advance. Tanks may be kept under pressure of carbonic acid gas or other non-inflammable gas.

Improvement in radius of action may be expected from improvements in motors, both in power for a given weight and in economy of operation.

The rubberized fabric of dirigibles at best allows a leakage of gas of about ½ per cent. to 1 per cent. per day. In a 500,000 cubic foot ship this is a serious matter, and in 10 days a loss of lift of 10 per cent. may result. Laboratory experiments show various oiled and varnished silks to be more gastight than rubberized fabrics, but such silks have not yet been made sufficiently strong and durable for practical use. Goldbeater's skin is gastight, but very expensive and difficult to handle. It may be expected that the future will bring forth an improved fabric.

Since the safety of a dirigible and its general usefulness depend to a large extent on speed, it is certain that every effort will be made to increase speed. The present speed of 50 miles per hour, when increased to 60 miles per hour, will give us a vastly more serviceable air ship.

At the present time a dirigible in thick fog, rain or snow is likely to become lost and unable to return to its station. The German Zeppelin which landed at Luneville, France, recently in a fog is a case in point. It was most embarrassing to the Germans to have the French authorities become familiar with details of this ship. Since then experiments have been made in Germany to guide dirigibles enveloped in fog by means of wireless signals sent from two points. The relative intensity of signals received from the two stations by the dirigible is proportional to the relative distances of the ship from those stations. The method is reported to have been of some assistance. We may look in future to a perfection of such methods of orientation.

The future will also doubtless bring a multiplication of air-ship stations, each lighted at night by distinguishing lights.

Automatic devices for regulating the ballonet pressure are under consideration and will probably prove of some help to the pilot.

In short, we may expect progress to be made in speed, power, radius of action, safety and reliability. It does not seem likely that it will be necessary to go to enormous sizes to accomplish this advance. Size in itself is a grave disadvantage.

Meteorology, though not a part of air-ship design, will lend valuable assistance in operation by a better knowledge of the atmosphere. A great deal of attention is being paid to the upper air currents, and it may reasonably be expected that the future meteorological forecasts will predict the conditions in the upper atmosphere with the precision of its present bulletins on conditions near the surface of the ground.

Improvement in the past five years has been very rapid, but there is yet hope that further improvement may be made and that in the near future the dirigible air ship will be not only an engine of war but a valuable agent in the service of commerce and industry.

Much of the expected improvement in the general utility of air ships may be expected to result from research in the aeronautical laboratories maintained by the governments of Germany, France, England and Italy. The practical application of these results of laboratory research will be made by the young men who are being trained as aeronautical engineers in the engineering schools.

THE NEW COOKE-POLLEN RANGE-FINDER.

By E. Wilfred Taylor.

Reprinted from "Journal of the United States Artillery," May-June, 1914.

In the early part of 1911 and after nearly ten years' experience with fire-control instruments, the Argo Co., Ltd.* began the design of a new range-finder with two distinct objectives in view:

(A) The greatest possible illumination.

(B) Invariability at all ordinary temperatures.

Hitherto the makers of self-contained horizontal base range-finders have had three grave difficulties to contend with:

1. The internal tube carrying an object glass at each end has always been open to the objection that inconceivably small buckling under unequal or different temperatures may result in very serious errors in range readings.

2. The variability of the solid glass pentagonal prisms. The Argo Co. and certain German experimenters had found that these prisms do not usually reflect off the rays at the same angle at all temperatures, some exhibiting much more serious variations in this respect than others. This is quite apart from the temporary deformation of figure which takes place in them when in course of changing temperature. Moreover, the size in which these prisms can be successfully made is strictly limited.

3. The law of the prism travelling parallel to itself between the objective and its focus is

$$d = \frac{DC}{F}.$$

d = shift of focus in circular measure, usually seconds of arc.

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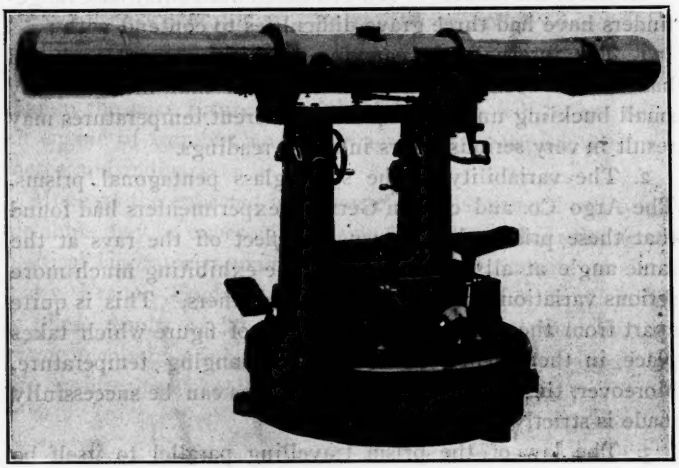
* Bishophill House, York, England.

D = distance of prism from the focus, or primary image.
F = focal length of the objective.
C = deviation given by the prism in circular measure.

For instance, C may be 10 minutes when D = F, or when the prism is close up to the objective. Here the full angular deviation C is obtained at the focus, or $d = C = 10'$.

$$\text{If } D = \frac{1}{10} \text{ of } F, \text{ then } d = \frac{C}{10} = 1'.$$

Since $\triangle d = \frac{C}{F} \triangle D$, a constant lateral movement of the prism wherever it occurs always yields the same shift of the image seen through it. But the shift, in seconds of arc, means an increment of range which varies as the square of the range,



COOKE-POLLEN RANGE-FINDER.

so that the least mechanical inaccuracy in the traverse of the prism may cause very serious errors at the long ranges. Consequently, the scale closes up rapidly as the long ranges are reached.

In the Cooke-Pollen Range-Finder these three fundamental

difficulties have been overcome in a novel manner that allows great accuracy of instrumental construction.

Its five characteristic features are:

1. *The total abolition of the double telescope looking opposite ways.*—Only one telescope is employed, the objective of which is of $3\frac{1}{8}$ inches aperture, the upper half receiving light from the distant object through the left-hand window of the instrument, while the lower half receives light from the distant object through the right-hand window of the instrument.

The area of each half of the object glass is $2\frac{1}{2}$ times the effective area of the objective in use in the usual 9-foot service range-finder; and this fact, together with the horizontal amplifying device and additional low power, as against the vertical amplifying system in use in the service instrument, gives a relative advantage in brightness of image of at least 8 to 1 for each eye alone in favor of the Cooke-Pollen instrument. If both eyes are employed, then the apparent luminosity is still further increased.

The horizontal magnification of the low-power eye lenses is 24 diameters, and of the high-power lenses 54 diameters; while the power in the vertical direction, wherein magnification is unnecessary and only wastes light, is half the above. Thus with the low power in use, the circular field of view appears drawn out into an oval.

It should be remarked that this great advantage of luminosity will not be observed so much in ordinary daylight; since the pupils of the eye are not then dilated enough to take in the extra light provided.

The extra magnification in the horizontal plane is brought about by the employment of two achromatic cylindrical lenses PA and NA which are shown in plan, Plate III. By this device magnification enough to show up conspicuously the defects in coincidence is obtained without the disadvantage of that loss of light which would inevitably follow if the vertical magnification were made equal to the horizontal.

2. *The total abolition of the solid glass pentagonal prisms hitherto employed as optical squares.*—After many trials and

experiments there has been devised a form of optical square, S_1 and S_2, which consists of two strictly parallel plane glass mirrors, silvered on their backs, mounted in a firm yet perperfectly free manner in a metal frame of nickel-iron having the same rate of thermal expansion as the glass. These have the great advantage that they can be as easily manufactured in large sizes as in small. There is one, S_2, rather larger than the other in the right-hand box a_2 of the instrument which is level with the lower half of the objective. This reflects the pencils of light received through the right-hand window W_2 and the swinging range prism P_2, along the bottom of the internal tube, past and underneath the left-hand optical square S_1 (which is mounted upside down with the lower edges of its two mirrors level with the center of the objective) and thence on to the lower halves of the three end mirrors M_1, M_2 and M_3, which reflect the pencils into the lower half of the telescope objective O. Similarly the pencils of light received through the left-hand window W_1 and the zero-setting prism P_1 (which is an exact duplicate of the swinging range prism P_2) is reflected by the upside-down left-hand optical square onto the upper halves of the above-mentioned three mirrors, which thus reflect the pencils under precisely the same conditions as those from the right-hand view, into the upper half of the telescope objective.

The reason why three reflections are here used instead of only two is to obviate the necessity for two reflections at the elbow of the telescope where the light is reflected at right angles into each eye. Apart from the optical squares, an even number of reflections must be used if the final view is not to be reversed left to right.

It has sometimes been objected that such silver behind glass mirrors must give false images reflected from their outer surfaces, but it can be shown that if they are truly parallel, as they can be made, and are employed solely for reflecting beams of practically parallel rays, then the images reflected from their outer surfaces will in the telescope exactly coincide with and reinforce the much more brilliant images reflected

from their silvered surfaces. As a matter of fact, no duplicate and fainter images can be detected. The loss of light from one of these silvered mirrors 30 inches thick is very small indeed; for, in the first place, the light reflected from the first surface is not lost, as explained above; and, in the second place, it has been proved by experimenting with many successive reflections, that a well-polished and well-silvered glass surface reflects internally 98 per cent. to 99 per cent. of light, so that there is only the 1 to 2 per cent. here to be added to 2 per cent. lost by absorption through the glass (one inch of borosilicate crown glass absorbs only 3 per cent.) leaving 96 to 97 per cent. of light effectively reflected from each mirror.

It will be clearly seen that, since each one of the three end reflectors M_1, M_2 and M_3, is one solid reflector one-half of which reflects the light from the right end of the instrument and the other half of the light from the left end, therefore the exact fixing or immovability of each of these mirrors is of no great moment; for, should one of them move, it is clear that both the upper and lower images in the same field of view will move together, so that coincidence will not be affected at all, unless the movement of the mirrors exceeds several minutes of arc, when very small errors may come in at the shortest ranges and at infinity and very long ranges, but no errors at all at the fighting ranges 6,000 to 10,000 yards.

It is only in the case of the two optical squares that any relative movements of the two constituent mirrors would be fatal; and, as these constitute the most vital elements in the whole construction, great care has been taken to obviate all likelihood of variability in the angles enclosed between the two mirrors composing them. A reference to Figs. 14 and 14a, Plate II, will show how these mirrors are mounted and secured in such a way that they are firmly yet freely held without any perceptible strain ensuing. It will be seen (Fig. 14, Plate II) that three pivoted pallets p, operated by springs, hold the mirror against three opposite pivoted fixed pallets. In order to obviate sliding friction of the metal pallets upon the mirrors the metal employed for the frames has a coefficient

of thermal expansion equal to that of the glass used for the mirrors. As a matter of fact, these frames might be of any other metal without any perceptible inaccuracy showing itself at different temperatures, provided the pallets embracing the mirrors can slide slightly but freely upon the glass surfaces and so allow for the metal expanding or contracting more than the mirrors. It is clear that under such circumstances the angle between the mirrors would not vary; but such friction under the allowed pressure of 5 pounds on each pallet, if repeated over a long period, might endanger the first contact surfaces and rub them away. Moreover, owing to the frictional resistance, most probably the most natural accommodation between frame and mirrors would take place by jerks. To obviate this the alloy of nickel-iron is used for the frames. It is carefully annealed and its coefficient of expansion may be counted on not to differ perceptibly from that of the glass.

In actual practice the stability of these optical squares at all temperatures is such that usually no alteration or adjustment of the coincidence is required after it has once been correctly set.

3. *The adoption of a swinging prism for neutralizing the angle of parallax.*—It is claimed that this device allows a greater degree of instrumental accuracy for the long ranges than can be obtained by the use of the prism sliding parallel to itself (which latter we have investigated earlier in this paper).

The swinging prism in the 9-foot base instrument is an achromatic prism giving a minimum deviation of about 17 minutes. When set for infinity or minimum deviation it is very nearly square to the line of sight. It is made to swing about an axis parallel to its refracting edge, or perpendicular to its plane of refraction, through an angle of about 42 degrees, when its extra deviation is about 10′ 20″, or enough to neutralize the parallax subtended by a 9-foot base at 100 yards.

The law of this swinging prism is $d = CA^2$, in which $d =$ shift in seconds;

C is the extra deviation given by the prism when turned one minute from its minimum deviation position; and

A is the number of minutes swing from the above position.

For instance, in the case of the swinging prism of the 9-foot base range-finder we have:

A = 1 minute	d = .000077	seconds.
A = 1 degree	d = .28	seconds.
A = 2 degrees	d = 1.11	seconds.
A = 3 degrees	d = 2.50	seconds.
A = 4 degrees	d = 4.45	seconds.
A = 5 degrees	d = 6.95	seconds.
A = 6 degrees	d = 10.01	seconds.
A = 7 degrees	d = 13.63	seconds.
A = 8 degrees	d = 17.80	seconds.
A = 9 degrees	d = 22.53	seconds.
A = 10 degrees	d = 27.82	seconds.
A = 12 degrees	d = 40.10	seconds.
A = 15 degrees	d = 62.60	seconds.
A = 20 degrees	d = 115.90	seconds.
A = 25 degrees	d = 189.	seconds.
A = 30 degrees	d = 281.	seconds.

The law, $d = CA^2$, holds good up to about 15 degrees of swing, when an additional deviation increasing as a higher power of A begins to be perceptible. This commences at about 8,000 yards range and increases up to 1,000 yards.

Thus the law, $d = CA^2$, holds good for all the longer ranges; so that differentiating, we have:

The variation on deviation = $\triangle d = C' 2A'$, where C' = .00077 seconds, or the extra deviation for the first minute of swing; and

A' = angle of swing in minutes.

Therefore, the longer the range the greater the change of swing required to produce visible effect. At 32,000 yards twice as much swing is required to produce a 1-second shift of the image as at 8,000 yards, so that the scale can be more open at the long ranges than in the case of the travelling prism,

and we are less dependent upon absolute accuracy in the position of the prism at long ranges.

The following table gives the shift of the image in seconds for a 1-minute alteration of swing at different ranges, supposing coincidence to have been obtained:

Range.	Shift per 1 minute.
1,000	.440
2,000	.310
3,000	.252
4,000	.220
5,000	.195
6,000	.178
7,000	.160
8,000	.150
9,000	.145
10,000	.138
12,000	.125
15,000	.112
20,000	.097
40,000	.069
50,000	.062

The lever which actuates the swinging prism is $7\frac{1}{2}$ inches long and one minute's swing therefore represents a movement of .00217 inch at the end of the lever, a very perceptible amount.

It will be seen from this table that at 8,000 yards range $6\frac{3}{8}$ minutes of movement are necessary to produce one second increment in deviation, implying an optical gearing down of 400 to 1.

Thus the device of the swinging prism lends itself to great accuracy of instrumental construction and operation.

The range scale is graduated every 25-yard interval and between the 1,000 and 20,000 is equicrescent, this result being obtained by the use of a cam C, Plate III, which governs the swing of the ranging prism P_2.

4. *The ready accessibility of the whole of the optical system of the instrument for cleaning purposes.*—The caps at each

end of the instrument, covering the mirrors and swinging prisms, are easily removed, rendering these elements accessible, while the optical elements carried inside the tube can be removed readily from the outside and after cleaning replaced without any fear of affecting the accuracy of the instrument.

It may here be mentioned that the platforms f_1 and f_2, Plate III, carrying the optical parts at each end of the instrument, are carried on platforms secured to an inner tube t_2. The only connections between the inner tube and the outer shell carrying the end caps are two pairs of pivots G. The inner tube is hereby rendered as free as possible from having transmitted to it any buckling or bending strains to which the outer tube may be subjected through strong sunshine on one side only. There is free air circulation between the inner and the outer shells.

It will be seen that any buckling transmitted to the inner tube to which the end platforms are fixed, taking place in the horizontal plane, cannot affect the coincidence, since the angles at the base of the range triangle are not thereby affected; for, although such buckling has the effect of causing the optical squares to rotate with respect to one another about their vertical axes, yet such rotation does not in the least degree affect the angle between the incident and reflected rays, which angle is always exactly double the angle between the two mirrors concerned.

Should buckling take place in a vertical plane, then a halving error ensues. This error can at once be rectified by turning the milled head U provided for this purpose, and cannot cause any error whatever in coincidence, once the optical squares have been correctly adjusted.

5. *The application of binocular vision as a supplementary but substantial aid to range-finding.*—The only serious obstacle to the binocular coincidence always superseding the usual cut as seen with one eye only, is the atmospheric turmoil of the images which generally exists, especially when the sun is shining. But towards and after sundown, when the light is so decreasing that the extra light given by large aperture plus

binocular vision is of the utmost importance, the mutual oscillation of the images rapidly declines; so that it may be said, the worse the light the steadier the image; and under such circumstances the binocular method of taking coincidence will, after a little practice, be found to give at least as great consistency of readings as does the usual type of instrument, together with the full benefit of the higher degree of instrumental stability which characterizes the Cooke-Pollen Range-Finder.

The binocular construction depends simply on an arrangement of prisms at the elbow of the telescope.

In the first place, the two images, as formed by light from the left-hand and right-hand ends of the instrument respectively, are formed upon the first surface or on the level of the ridge of the separating prism, SP, lower figure, Plate III, shown in vertical section in Fig. 10, Plate II. This prism is united optically with the achromatic first lens (called the *halving lens*) of the four-lens eye piece system. The two acting together cause two overlapping images of the object glass to be formed about level with the middle of the left-hand prism, Figs. 12 and 13, Plate II (r_1, Plate III). Figs. 11 and 12 are views of these overlapping images—pupillary images, as they are generally called. The left prism, Figs. 12 and 13, has a slot cut right through it just allowing to pass all the light constituting the two overlapping half images, *b* and *t*, of the objective, while the light constituting the uppermost and lowermost half images, B and T, is reflected by the left prism into the left achromatic erector lens E_1, Plate III, which projects an erected image of the object on the back surface of the left field lens e_1.

On the other hand, the light passed through the slot in the left prism, passes on to the right-hand prism r_2, Plate III, by which it is reflected into the right erector lens E_2, which projects an erected image of the object into the right field lens e_2, the image being formed about $\frac{1}{8}$ inch behind the latter.

In Figs. 11 and 12 the uppermost half pupillary image, B, is an image of the lower half of the objective; that is, it is

formed by light from the right-hand window wherewith the objective forms an upside-down image upon the lower half of the separating prism. (Fig. 10). This constitutes really the upper half of the real object or field of view seen from the right end of the instrument, and is projected by the upper part of the left prism and erector lens into the upper half of the left field of view.

Similarly, the lowermost pupillary image T is an image of the upper half of the objective; that is, it is formed by light from the left-hand window wherewith the objective forms an upside-down image upon the upper half of the separating prism. This constitutes the lower half of the real object or field of view seen from the left end of the instrument, and is projected by the lower part of the left prism and erector lens into the lower half of the left field of view.

Of the two overlapping pupillary half images, in Figs. 11 and 12, one, *t*, is an image of the upper half of the objective formed by light from the left window which forms an upside-down image upon the lower half of the separating prism. This constitutes really the upper half of the real object or field of view seen from the left end of the instrument and is projected by the right prism and erector lens into the upper half of the right field of view.

The other overlapping pupillary half image, *b*, in Figs. 11 and 12, is an image of the lower half of the objective formed by light from the right-hand window which forms an upside-down image upon the upper half of the separating prism. This constitutes really the lower half of the real object or field of view as seen from the right end of the instrument, and is projected by the right prism and erector lens into the lower half of the right field of view.

Thus the upper half of the right field and the lower half of the left field together constitute the whole image as seen from the left-hand window, while the upper half of the left field and the lower half of the right field constitute the whole image as seen from the right-hand window. Fig. 1, Plate I, shows this diagrammatically.

Therefore, if the instrument is set for infinity and then directed to a finitely near object, the right-hand view *r* of the object in Fig. 1 must appear displaced towards the left of the left-hand view of the object. That is, in the right-hand field of view *r*, Fig. 1, the lower image is displaced to the left, while its continuation in the left-hand upper view is also displaced to the left (see *l*, Fig. 1). Therefore, in the right field, the lower image appears displaced to the left; while, in the left field, the lower image appears displaced to the right. Consequently, if the eyes binocularly converge upon the lower images so as to merge them into one, as in C, Fig. 1, then the upper images simultaneously appear separated at equal distances at either side of the lower image. Or if the eyes are made to binocularly converge or diverge upon the lower images so as to merge them into one, as in C, Fig. 2, then the lower images simultaneously appear separated at equal distances on either side of the upper image. Thus, when coincidence is not obtained, it is impossible to see both upper and lower images single simultaneously, so as to appear as solid and continuous right across the halving line.

Makers of large range-finders employing pentagonal prisms have found it necessary to provide means for adjusting the instrument at any time without the aid of external objects. A pair of small pentagonal prisms are used and they admit parallel rays of light into the larger prisms. Ingenious devices are used to eliminate errors due to the variability of the smaller prisms.

Owing to the great stability of the optical parts in the C.-P. Range-Finder it is usually quite unnecessary to alter the coincidence, once it has been correctly set. As in other instruments, it could be set on a star or on the moon. A special adjuster which can be used at any time is also provided. Above the left eyepiece is a milled head and toothed wheel, and on the latter figures are engraved at approximately 1-second intervals. An alteration of one second will cause the following errors at the given ranges:

Range.	Range error caused by instrumental error of 1 second.
20,000,	± 648 yards.
15,000,	± 364 yards.
10,000,	± 162 yards.
9,000,	± 131 yards.
8,000,	± 104 yards.
7,000,	± 79 yards.
6,000,	± 58 yards.
5,000,	± 40.5 yards.
4,000,	± 26 yards.
3,000,	± 14.6 yards.
2,000,	± 8 yards.
1,000,	± 2 yards.

It is not anticipated that occasion will arise for readjusting of the coincidences, but it is as well always to have at hand a ready means of testing and adjusting coincidence without having to depend upon the sighting of celestial objects, which are not always to be seen when wanted.

Therefore, there is supplied a zero or coincidence tester and two collimator lenses, C_1 and C_2, with each instrument (Fig. 16). This is simply a device for presenting to the view of the range-finder two vertical black marks at a distance apart equal to the base length. The front view of the zero tester is given in the top figure of Plate III, where L. M. is the left-hand mark and R. M. is the right-hand mark. This instrument is made of materials corresponding to the range-finder itself, a precaution necessary for securing equality of distance at all temperatures between the centers of the windows of the range-finder and the distance beween the two sighting lines as shown in Fig. 16.

Two collimator lenses, C_1 and C_2, are provided in glass cells, each of which fits easily into the window openings of the range-finder. The purpose of these collimator lenses is to make it possible for the range-finder to focus upon the zero tester marks at the distance of 170 feet; that is, to render the

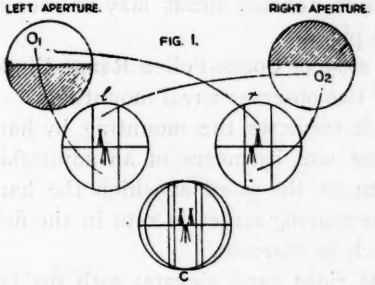
rays diverging from each mark about parallel, as if coming from a mark at an infinite or very great distance.

The range-finder should first be adjusted against halving error on some fairly distant object; and then, after having the collimators placed in position, the range drum must be set to the infinity mark and the instrument directed to look downwards to the distant zero marks.

The zero tester has screwed in its center a little sighting telescope. This is directed so that a circular white mark painted on the center of the range-finder is seen in the center of the field. Fig. 19 shows the view which should be seen through the sighting tube where the white spot is seen in the center of the little circle, while the horizontal line is set about parallel to the range-finder cutting through the center of its windows. So long as the sighting tube centers strike the range-finder within 10 inches left or right of the white spot the pointing is sufficiently accurate.

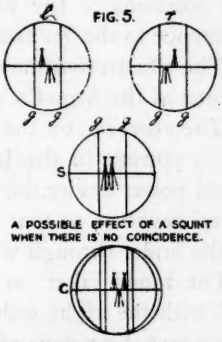
In the meanwhile, the observer at the range-finder is supposed to have directed the instrument so that the left window faces the left end of the zero tester, while the right window faces the right end. What he should see in the field of view of the right eye is shown in Fig. 15. The upper mark must be kept in the middle of the field, and for this purpose it is preferable to use the right eye only. Should there be any want of parallelism in the vertical plane between zero tester and range-finder, then the diagonal marks in upper and lower fields will not intersect in a common point in the halving line. He should then signal to the man at the zero tester to raise or lower one end of the latter until the diagonal lines about intersect to form a St. Andrew's cross with the center blank as in Fig. 15. This zero tester may be permanently fixed up at the correct distance from the range-finder mounting, when it will only be necessary to direct the instrument thereon.

Any discrepancy between the vertical lines as seen in the top and bottom fields is corrected by the aforesaid coincidence wheel.



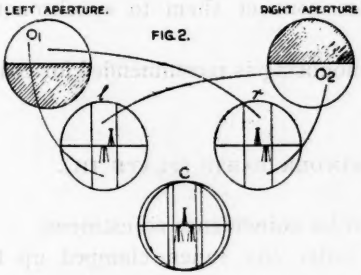
SHOWING ORIGIN & DISTRIBUTION OF THE IMAGES.

INSTRUMENTAL READING LONGER THAN REAL RANGE.

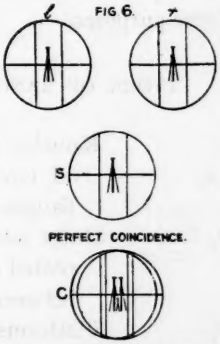


A POSSIBLE EFFECT OF A SQUINT WHEN THERE IS NO COINCIDENCE.

BUT ON BRINGING LOWER IMAGES INTO ONE BINOCULARLY, THE OTHER TWO SEPARATE MORE.

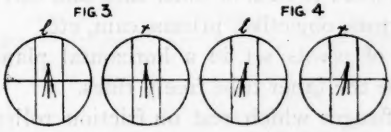


INSTRUMENTAL READING SHORTER THAN REAL RANGE.



PERFECT COINCIDENCE.

EFFECT OF A SQUINT WHEN THERE IS PERFECT COINCIDENCE ON BRINGING LOWER IMAGES INTO ONE BINOCULARLY, THE THER TWO ALSO COALESCE INTO ONE.



HALVING ERROR OF EXCESS. DEFICIENCY.

HALVING CORRECT, BUT COINCIDENCE WRONG.

PLATE I.

All adjustments are made from the outside of the tube, and the positions of the various knurled heads may be seen on reference to the sectional plan.

The illustration shows a 9-foot Cooke-Pollen Range-Finder on one of the Argo Co.'s* two-observer naval mountings.

The observer on the left traverses the mounting by hand or by power; in the latter case, by means of an adjustable-speed power device, he can set the speed at which the hand wheel revolves so that the moving target is kept in the field of the finder through which he observes.

The range taker on the right hand elevates with the left and with the right either ranges by hand or power. In the latter case, by means of an adjustable-speed power device he can set the speed at which the hand-wheel revolves.

Range-Azimuth transmitters are attached to the stationary base, and multi-core cables connect them to synchronous numerical indicators.

A simpler form of this mounting is recommended for coast defense purposes.

INDEX OF RANGE-FINDER PARTS (PLATE III).

A	Knurled head for coincidence adjustment.
a_1, a_2	Oval covers outer and inner, clamped up to flanges on outer tube.
t_1, t_2	Outer and inner tubes. The inner being supported only by two pairs of pivots G. Space between open to ventilation.
f_1, f_2	Platforms fixed to ends of inner tube and carrying mirrors, objective, prisms, cam, etc.
G	Two sets of pivots set in a horizontal plane. On these the inner tube freely rides.
T	The two flanges which rest on friction rollers carried by the mounting.
W_1, W_2	Plane parallel glass windows.

* Bishophill House, York, England.

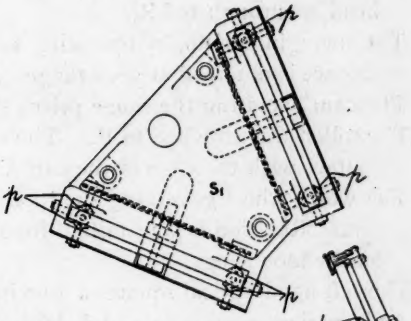


FIG 14.

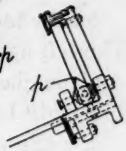


FIG 14 a.

FIG. 10.

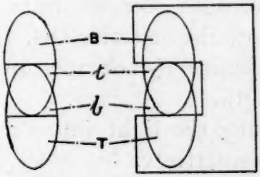


FIG. 11. FIG. 12.

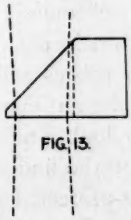


FIG. 13.

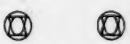


FIG. 17.

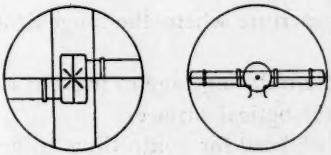


FIG 15 FIG 19

FIG. 18.

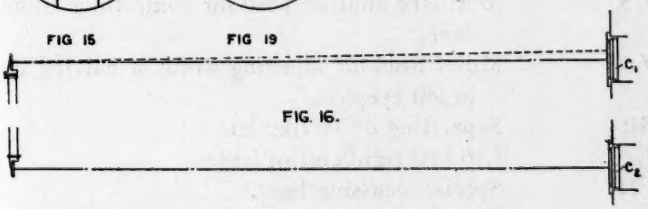


FIG. 16.

PLATE II.

P_1	The zero-setting prism. Operated by knurled head A through rod R_1.
P_2	The swinging prism, by operating which coincidence is obtained at each range.
C	The cam operating the range prism P_2.
L	The roller arm attached to P_2. The roller is in contact with the edge of the cam C.
x	The worm wheel governing the rotation of the cam. Rotation is transmitted from a handle on the mounting.
S_1	The left-hand optical square of two immovable plane-glass mirrors in a nickel-iron frame.
S_2	The right-hand optical square. This is capable of a slight tilt for adjusting halving.
U	The knurled head for adjusting halving.
M_1, M_2, M_3	Three circular parallel glass silvered mirrors. These reflect the light received from both optical squares into the objective OG.
OG	The achromatic objective $3\frac{1}{8}$-inch aperture and 53-inch focal length.
r_1, r_2	Two prisms reflecting the light into the left and right eyes, respectively.
FP	Two doubly-reflecting prisms turning the light into the finder eyepiece.
RD	Glass-protected aperture where the range drum is read.
DC	Chloride of calcium drying cage to prevent the bedewing of the optical surfaces.
HR	Auxiliary knurled head for controlling coincidence.
d	Milled head for adjusting width of halving line in left eyepiece.
SP	Separating or halving lens.
E_1, E_2	Left and right erector lenses.
FH	Special focussing head.
e_1, e_2	The two eyepieces.

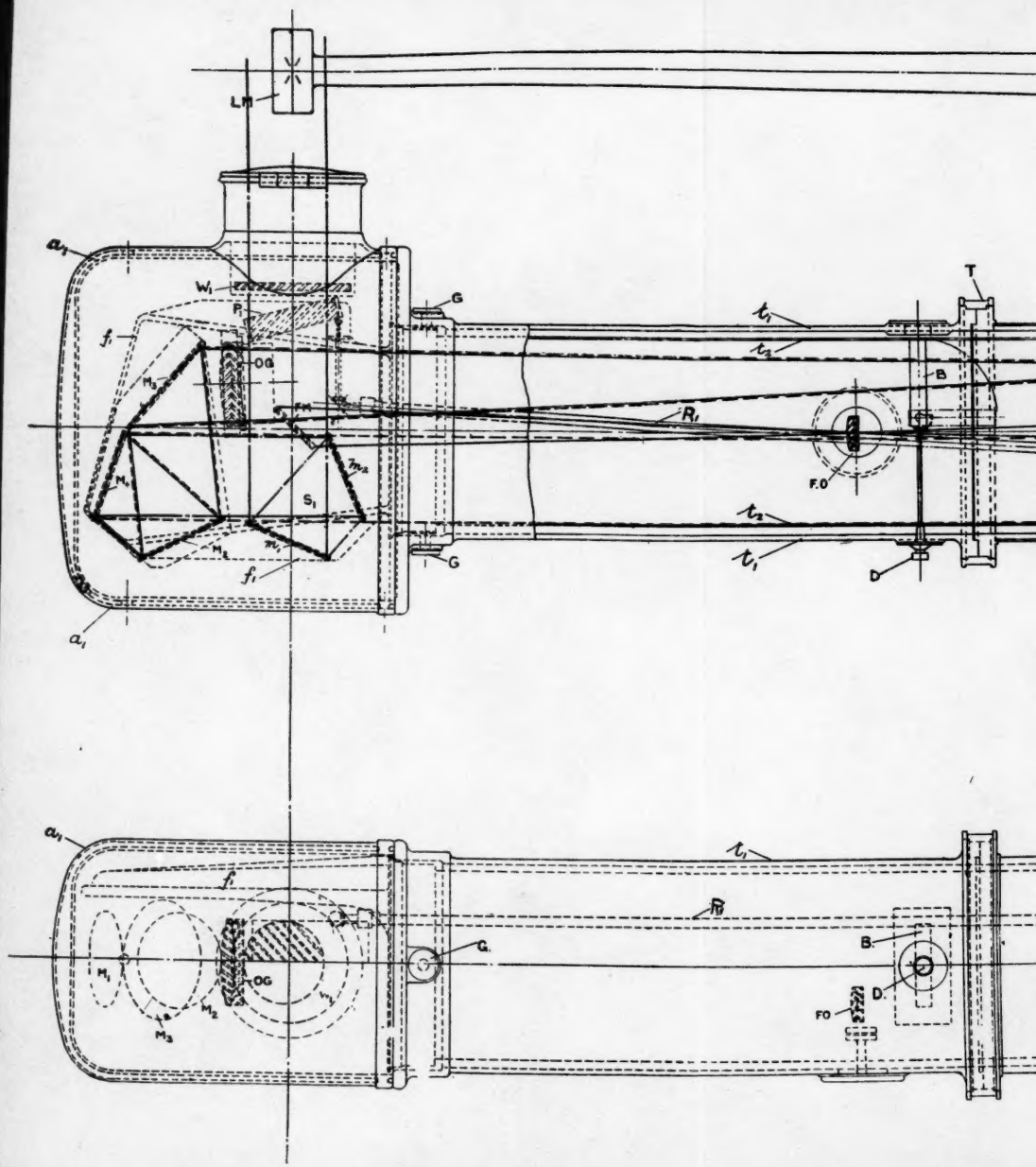


PLATE I

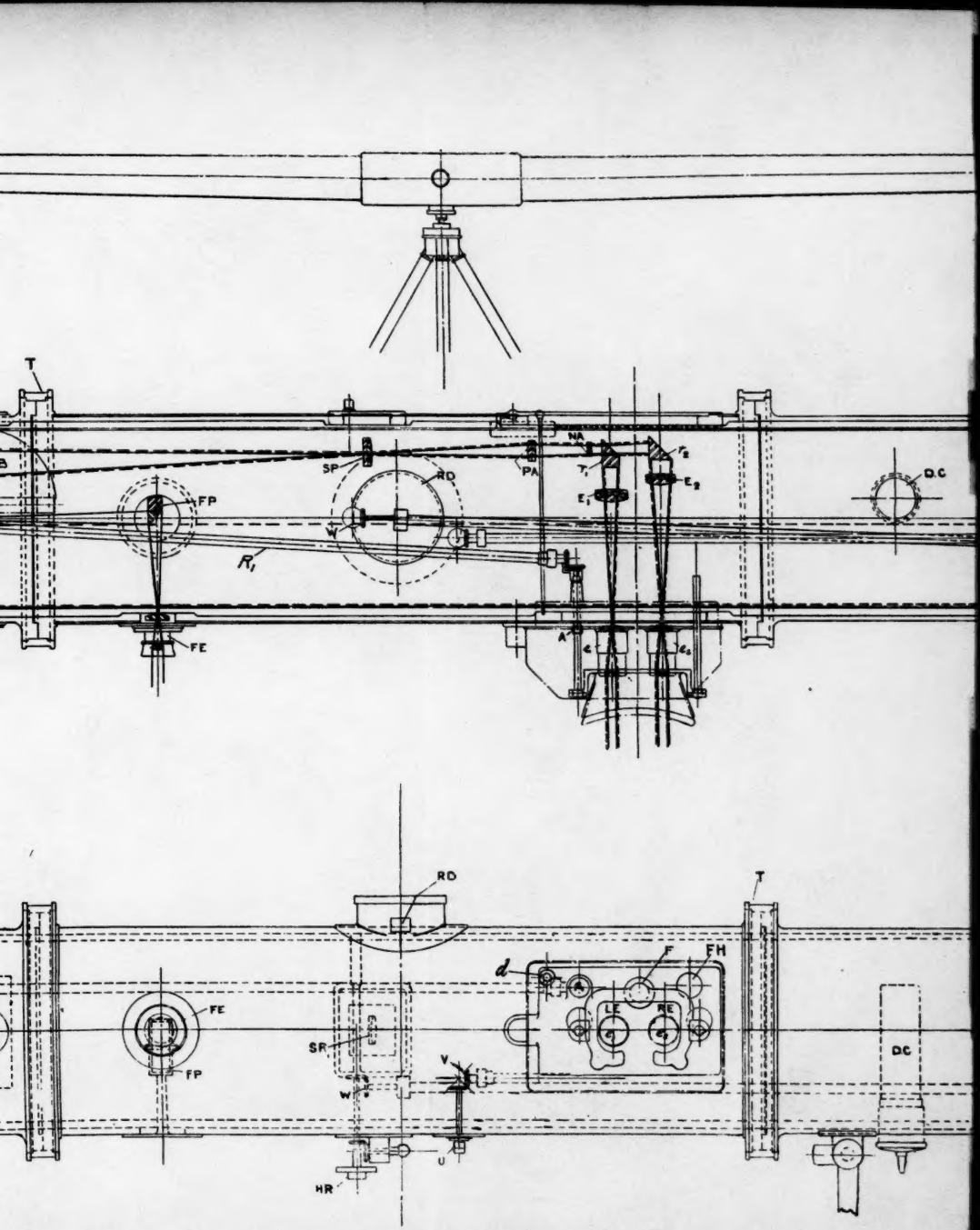


PLATE III.—GENERAL ARRANGEMENT OF THE COOKE-POLLEN RANGE-FINDER.

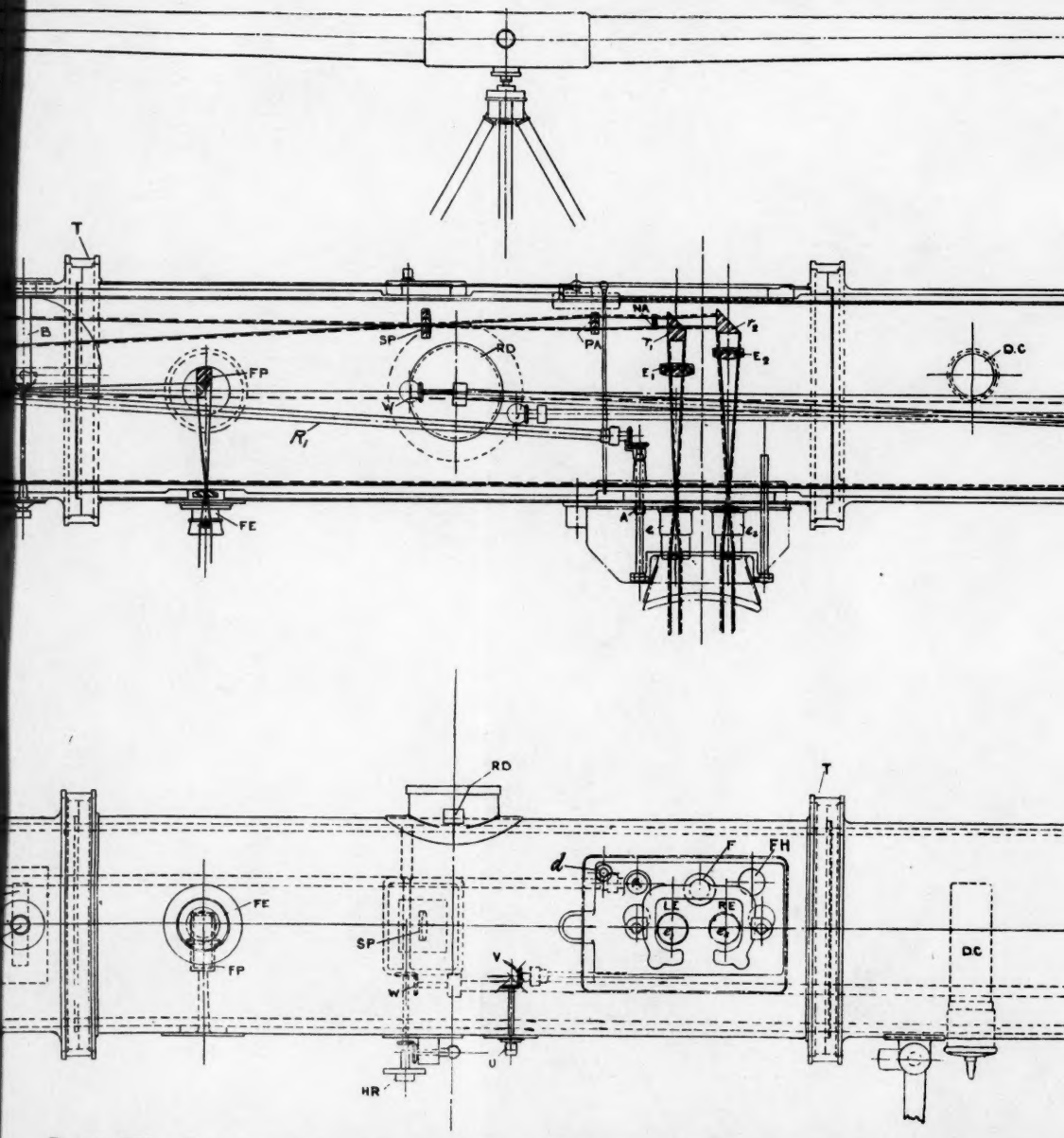
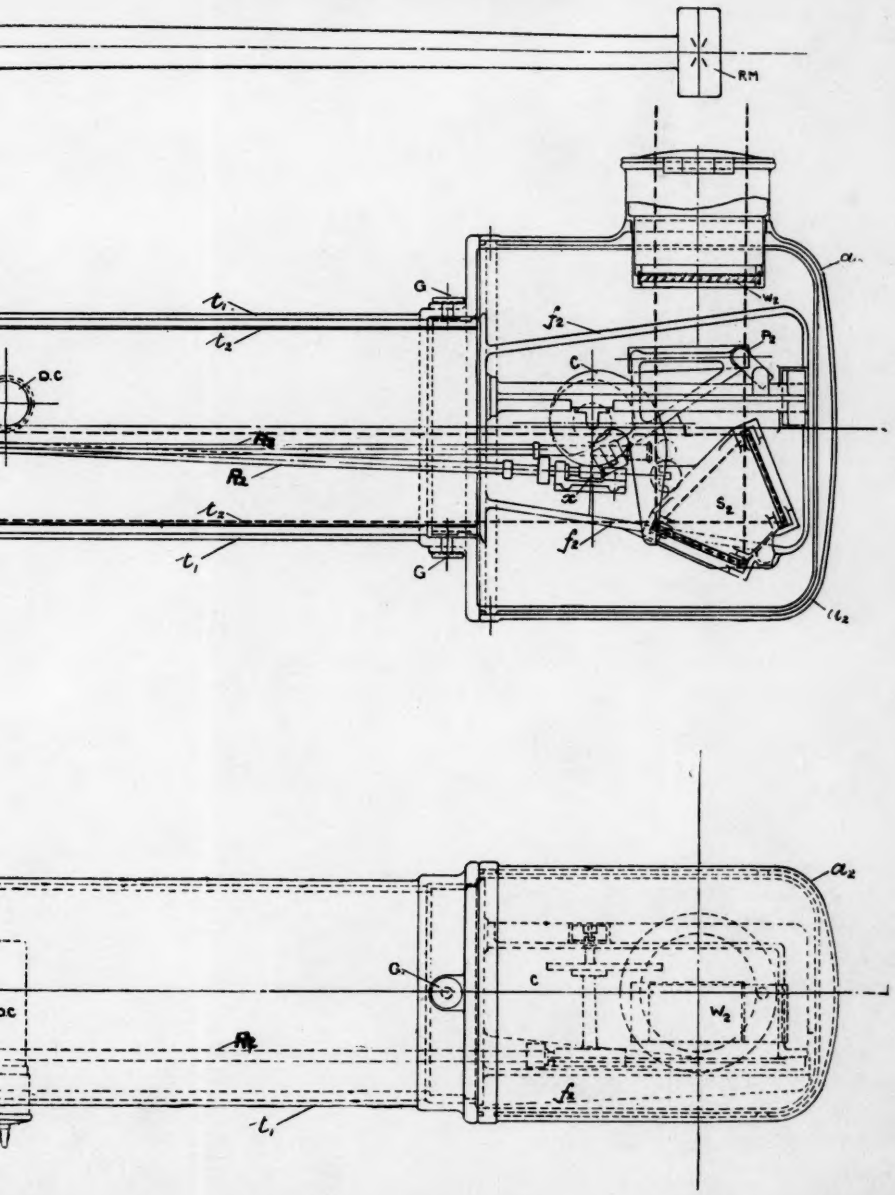


PLATE III.—GENERAL ARRANGEMENT OF THE COOKE-POLLEN RANGE-FINDER.


RM
a_1
t_1
t_2
G
f_2
P_2
C
O.C
P_1
P_2
L
x
S_2
t_2
t_1
G
f_2
a_2

a_2
G
C
W_2
P_1
f_2
t_1

FM	Finder mirror.
FO	Finder objective.
FE	Finder eyepiece.
B	The astigmatizer lens.
D	Knurled head operating the latter.
LM and RM	The two ends of the zero tester.
PA	Positive amplifying cylindrical lens.
NA	Negative amplifying cylindrical lens
F	Focusing screw.

[Grateful acknowledgement for permission to reprint this article, and for loan of cuts is extended to the "Journal United States Artillery."]

SUBMARINE SIGNALLING.

By Lieut. (J. G.) W. R. Carter, U. S. N.

The main reason why submarine signalling, or signalling under water, is of such vast importance to us is due to the fact that the medium, water, through which the sound is to travel is uniform. The sound, therefore, will not be deflected or reflected as it is in air. The medium air Professor Tyndall has demonstrated to be non-uniform. For signalling between surface vessels in foggy weather, where direction is of such paramount importance, the medium air is not to be depended on. For signalling between submerged submarines water must, of course, be the medium. In both cases it is apparent that underwater signals are of infinite value. In order to have submarine signalling we have two problems: First, we must have an apparatus which will transmit sound through water. To be of any great practical value, in these days of fast ships and crowded water traffic, the apparatus should transmit sound several miles. The sound having been transmitted our second problem is to receive it.

Years before we ever thought of making any practical use of submarine signalling the Cingalese fishermen used an earthen bowl, called a chatty, for this purpose. The fishermen in one boat would put his chatty overboard and strike it sharply beneath the water, sending signals to a nearby fisherman, who heard them by putting his ear at the bottom of his boat. The distance the sound was heard was, of course, entirely too short to be of much use in this day. Probably the Cingalese could not in any way explain or account for the phenomenon of sound in water beyond knowing that the fact existed. The idea of signalling, however, is his and not ours.

As far as can be ascertained, with the exception of the Cingalese, an Englishman, Henry Edmunds, was the first person to attempt to use the knowledge of sound transmission through water for signal purposes. In 1870 he obtained a patent in which he outlined a crude method of striking an electric gong under water. He also described a method of attaching a bell to a buoy, which bell was to be struck by a clapper actuated by the tossing of the buoy. For the receiving apparatus he proposed two schemes, one of which was that of a submerged telephone transmitter, which he thought might be made to pick up the sound and transmit it to a listener at the receiver; the other scheme he proposed was to apply the ear to the handle of an oar, the blade of which was thrust into the water. While Edmunds' plan was never of any practical use, it started things in the right direction and he should be given credit for his idea. Since then there have been several schemes of submarine signalling proposed and experimented with by both foreign and American inventors, among them Thomas A. Edison of this country. None of the plans were sufficiently successful to warrant commercial adoption.

In 1890 Mr. Arthur J. Mundy of Boston, realized that submarine signalling was possible, but that in order to be carried to that point of perfection which would make it of commercial and practical value, the idea should be worked upon by experts of technical and business ability. He interested several men of this character, forming a syndicate, and proceeded with the development of the scheme. There were varying degrees of success in using a bell. When a bell was struck under water it could be heard a considerable distance by means of a submerged telephone transmitter, if the latter was stationary and the sea calm. For a long time no apparatus was found which could be installed in a vessel and transmit sound a sufficient distance. Neither could any receiving apparatus be designed which would not become useless on a moving vessel. The noises of a moving vessel and the noises of the rushing water outside the vessel were such as to make it impossible to detect the

note of the bell. This was due, no doubt, to two reasons, one being that the mechanisms used were crude, and the other that the pitch of the bell note was not sufficiently high to make it distinguishable from the vibration noises of the vessel and the noises of the rushing water. Many experiments were tried. Telephone transmitters were suspended in the water; holes were cut in the vessel and tubes, some filled with water and some with air, leading up to receivers were tried; inserting diaphragms in skin of ship was tried; but in all those it was impossible to get rid of the foreign noises due to vessel machinery, waves, etc. Attempts were made both to tune out and to insulate these noises. It was found that they could not be tuned out; and when insulated, the bell note was insulated to the same extent.

It was discovered by Mundy himself that water on both sides of the skin of a ship formed practically a uniform path of transmission from the bell to the microphone of the receiver. This discovery was of such importance that it led up to the formation of a new and larger company being incorporated in 1901. This was the Submarine Bell Company of Boston.

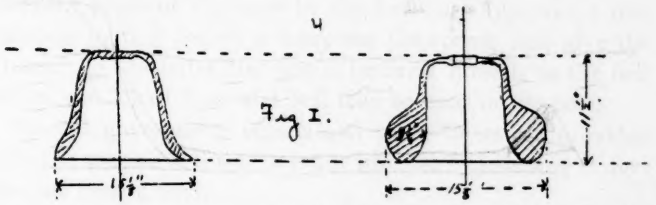
I do not wish to convey the idea that the Submarine Bell Company of Boston is responsible for the only idea of submarine signalling, for it is not. Having been detailed for duty on submarine vessels which were fitted with this company's apparatus, I am more familiar with the history, mechanical arrangement and practical use of this particular apparatus than with any other.

From 1901 on, there has been step by step improvement in submarine signalling, in which, to the best of my knowledge, the Submarine Bell Company has led all competitors.

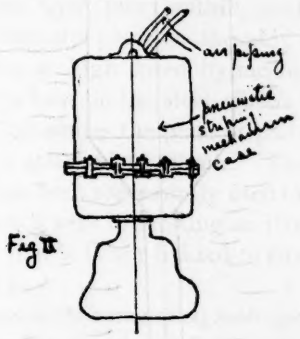
THE SENDING APPARATUS.

Experiments with several types of bells, differing in shape, weight and material were tried. Some of the bells were of bell metal and some were of steel. Locomotive bells, church

bells and hand bells, ranging in weight from 300 pounds down to 10 pounds were tested. The tests finally developed a 220-pound bell having a period of about 1,215 vibrations submerged. Figure I, shows a comparative sketch of this bell with an air bell.



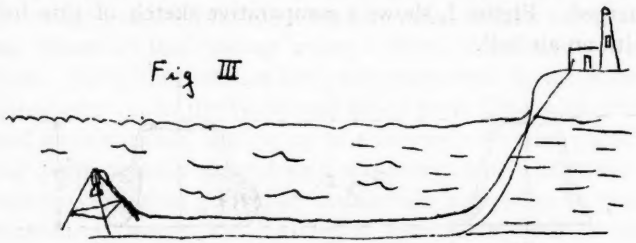
The striking mechanisms of the bell are different for different uses. The bells installed on light vessels and on submarines are operated by a pneumatic mechanism. (See Fig. II for a general sketch without details.)



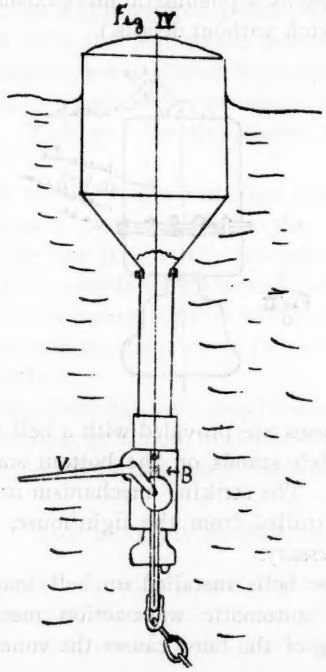
Some lighthouses are provided with a bell suspended in a tripod frame which stands on the bottom some distance off shore (Fig. III). The striking mechanism in this case is an electric one controlled from the lighthouse, where a small generator is necessary.

The submarine bells installed on bell buoys are usually operated by an automatic wave-action mechanism. The rising and falling of the buoy causes the vane V (Fig. IV) to

compress a spring within the mechanism box B which automatically releases itself and the bell is struck. The release occurs only after a definite compression has been given the



spring, and this of course gives the same intensity of bell stroke each time. If the sea is very rough the bell will be struck very often, and if the sea is calm only the ocean swell will



cause the buoy to rise and fall and hence the bell will be struck very much less often, but always with the same intensity.

The hand bell is made in two types, one with the accumulative action and the other without it. In the former a lever takes the place of the vane in the bell-buoy type and a line attached to it is pulled to compress the spring and give the stroke. In the latter the line is fastened directly to the bell striker. A small 20-pound bell may be used in life boats.

Several government vessels and some liners are provided with the marine bell which is put into use by lowering it over the side from a davit.

Another form of sending apparatus has been produced by an Austrian inventor and physicist named Berger. His method is to produce the sound vibration by means of a vibrating sheet of metal. This he accomplished by stretching a steel ribbon from a point of attachment on the interior of the skin of a vessel to some fixed point within, such as a piece of framing, or to an opposite point on the skin of a vessel. A raw-hide disc, spun at high speed by means of an electric motor, is brought to bear on the steel ribbon by means of an electric clutch. This causes the plate or plates of the skin to which the ribbon is attached to vibrate. This scheme while not yet perfected has been successfully used to send signals on some occasions, and is very interesting and brings in a somewhat new field, in that it is not limited to any fixed period of vibration as a bell is.

There is still another scheme of signalling along somewhat similar lines to the last-mentioned for which Professor Reginald Fessenden* is responsible. In this the vibration of a plate is accomplished by means of a large electric solenoid. An extension of the core of secondary coil of the solenoid is secured to the skin by an electric weld. The primary coil is held rigid in a frame-work which is secured by bolts or rivets

* See July 4, 1914, "Scientific American" for details of the Fessenden oscillator. The article in the "Scientific American" called, "An Underwater Siren to Prevent Collisions at Sea," which was published after the article on "Submarine Signalling" was submitted, gives the details of the Fessenden oscillator or vibrating-plate scheme, and by following out the description with the aid of figures 1 and 4 of that article a very comprehensive idea of the device may be obtained.

to the frame of the vessel. A motor-driven A. C. generator furnishes the current.

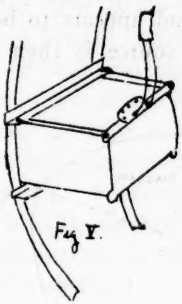
Professor Fessenden has adapted his scheme for telephonic communication also, but the distance over which it can be heard is very short.

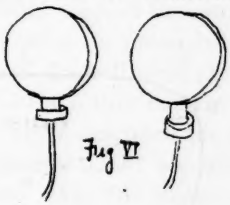
A comparison of the bell with the two last mentioned devices demonstrates the fact that the vibrations given out by the bell go out in all directions as if sent from the center of a circle to all radial points, whereas those from the plate vibrated by either of the above means are more limited in their field, being stronger in the direction of the normal to the plate, and of very little if any strength in a direction parallel to the plate.

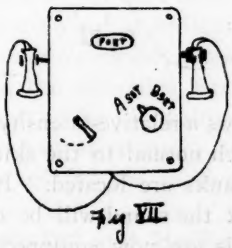
It has been found that with the plate apparatuses in good working order and tuned to a high pitch the intensity in the direction normal to the plate was greater than the intensity of the bell in the same direction, and that the former could be heard at a greater distance than the latter. Some experimenting has been done to make comparisons of these methods, and the above facts concerning the strength and field of vibrations were established. The sound given out from the plate is that of a shrill whistle. The electrical actuating gear is such that a sending key may be used, as in wireless, and the regular Morse code of signals utilized, which permits of signalling much more rapidly and with greater accuracy than with the bell. Some very remarkable claims as to the distance at which the vibrating plate or oscillator has been heard have been made. The writer, who took part in some tests carried out along these lines in August, 1913, is not prepared to corroborate all these. There is no doubt, however, that the scheme is an excellent one, and if it can be improved so that sound vibrations may be sent in all directions, the vibrating plate apparatus will no doubt take the place of the bell as a message-sending device. With all battleships provided, the value of an effective submarine sending set would be tremendous, both in foggy weather and in battle where the radio may be rendered useless by enemy's fire.

THE RECEIVING APPARATUS.

After the discovery that water on both sides of the skin of the ship formed practically a continuous path for the receiving of the vibrations, the following apparatus was made up to detect the bell note. Two cast-iron tanks are placed inside the vessel against the skin, the latter forming one side of the tank. The tanks are placed one on each side well below the water line and from 20 to 150 feet abaft the stem, depending on the size and shape of the vessel. They are filled with salt water, and in each two microphones are suspended. Figure V shows sketch of tanks. Figure VI shows microphones.







The microphones are connected to telephone receivers which in surface vessels are usually situated in the pilot house. The microphones are divided into two sets, called the A set and the B set, and one of each set is on each side.

They are independently connected and lead to an indicator box where a switch enables the operator to use either set. (See Figure VII.) The sets are arranged in duplicate in this manner in order to check results of one by the other, and to provide against the derangement of either. The telephone receivers lead from the indicator box fitted with switches by means of which the listener may use either starboard or port microphones. The idea is to determine on which side the sound is of greatest intensity, thereby determining the direction of its source. If the exact direction of the source is desired, the ship may be swung towards the side on which the sound is louder until the sound is heard louder on the other side. Then swinging back again through a small angle, this operation is continued until the sound appears to be of the same intensity on each side. The source is then directly ahead.

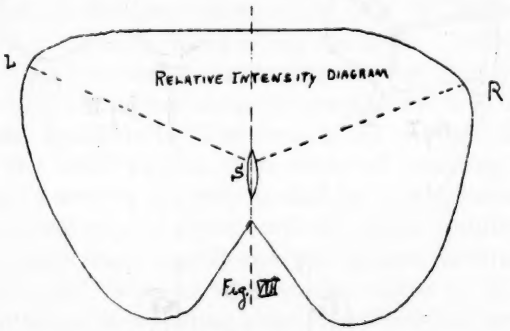


Figure VIII shows a relative-intensity diagram. The lines SR and SL are each normal to the skin at the point where the microphone tanks are located. It is in the direction of those lines that the sound will be of greatest intensity. About 1,000 vessels are now equipped with this receiving apparatus which may be used to receive the sounds from the two vibrating-plate apparatuses as well as the bell note. The sound of propellers of passing vessels has often been detected by this.

For the vibrating-plate sounding set which is operated by the solenoid, the receiving set is somewhat similar to the wireless. The sound vibrations striking the plate are in some manner, which I do not clearly understand, transmitted back through the solenoid in the same fashion that vibrations are received back through a wireless aerial.

No efficient receiving set for the Berger apparatus has been put forward.

A few accidents showing the importance of submarine signalling are: In 1908 when the *Republic* was rammed by the *Florida* in a fog, the sinking *Republic* sent a wireless call for help, saying that she was within sound of the submarine bell on Nantucket Light-ship giving her approximate latitude and longitude. The *Baltic*, which had already passed Nantucket Light-ship, inward bound for New York, received the message and turned back until she came within range of the submarine bell of the Light-ship. From that point she proceeded in zig-zag courses keeping within range of the bell until she found the *Republic*. Captain Ransomo, of the *Baltic*, in an article in the "Outlook," February number, 1909, described the rescue, saying that his zig-zag courses covered about 200 miles, all within an area of 10 square miles. Had the *Republic* been equipped with a bell she would have been found 10 or 12 hours earlier. Had the sea been rough, she would not have been found at all, because she would have foundered before the 12 hours elapsed. Submarine Signal Bulletin No. 42, gives the following: "The steamer *Rosecrans*, mistaking in the fog the North Head Light for the Columbia River Light-ship, was wrecked at Peacock Spit. The Light-ship was equipped with a bell, but the steamer had no receiving apparatus. Thirty-two people were drowned and the survivors suffered untold hardships."

"The *Uranium*, wrecked near Halifax in a fog, passed within two and one-half miles of the submarine bell at Chobucto Head. She was not equipped with a receiving apparatus."

Numerous other cases might be given where submarine

signalling might have prevented disaster and still others where it has prevented it, but it is the future possibilities which seem to me should demand consideration in the naval service. It is a well-known fact that when the Navy turns its attention to anything, that thing takes great bounds in improvement. Now if this should be done and submarine signalling so improved that battle signals could be transmitted by this means what a help it would be to the fleet. Picture one submarine with two or three feet of periscope occasionally showing leading half a dozen completely submerged vessels into an attack. Over a year ago one submarine running at a depth of one hundred feet received courses by submarine signal from another submerged directly over her with periscope exposed. These two submarines ran on various courses for over an hour keeping their relative positions. This was, of course, of no great practical value, but serves to illustrate what may be done in the future with a sufficiently improved apparatus.

NOTES ON EVAPORATING PLANTS.

By Lieut. Commander H. C. Dinger, U. S. N., Member.

The question of evaporators on naval vessels was extensively treated in an article by Commander E. H. DeLany, U. S. Navy, in the May, 1911, number of this Journal. Since that date there has been considerable improvement in the economy of evaporating plants on our naval vessels, secured along many of the lines indicated by Commander DeLany, who probably has gone into this subject to a greater extent than any officer of the Navy.

The Lillie distilling apparatus installed on the *Dixie* and described in the February, 1913, number of the Journal of American Society of Naval Engineers is by far the most economical plant ever installed for marine use. This plant, however, operates under a vacuum, and various practical troubles experienced with it have as yet apparently not warranted the Department in authorizing its installation on fighting vessels. (A plant of this type has been installed on the U. S. S. *Salem.*) It is, however, believed that the difficulties encountered in this first and more or less experimental installation can be properly overcome, though of course the operation of the plant would not be as simple as the ordinary type now being installed.

Some additional notes based on present experience are here given. Some of the conclusions are based on actual results, others on reports of performances and investigation.

POSSIBLE ECONOMY OF PLANTS INSTALLED.

A great deal of steam is wasted in most evaporating plants. As the conversion of the heat of the primary steam into the vapor is a simple matter, the amount of steam required can

easily be calculated, and if the steam consumed is much in excess it will at once indicate that something is wrong. In a single-effect evaporator the steam put into the evaporator should not greatly exceed the water evaporated.

When a feed heater is employed the steam used should not exceed the vapor produced by more than 10 per cent. This allows for a loss of more than 10 per cent. due to leaks, radiation and loss through the drains and for blowing down. On this basis the following results should be obtained.

With no avoidable losses one pound of primary steam should be able to evaporate the following amounts of vapor:

Single effect,	.9 pound.
Double effect,	1.7 pounds.
Triple effect,	2.35 pounds.
Quadruple effect,	3.2 pounds.

On this basis a double-effect plant of the type usually found on our battleships, if run in a very efficient manner, should produce about 4,000 gallons of water per ton of coal, assuming an evaporation of 9 pounds of water per pound of coal. In actual practice our evaporating plants are operated with a result much lower than this, though in some cases coming under the writer's observation over 3,000 gallons per ton of coal have been produced. The causes for this lack of economy are various, a number of the most important will be mentioned.

Loss Through Drains.—Traps are usually installed, and these frequently leak or are allowed to have their by-pass open. This is the greatest source of waste. An ideal trap, always tight, will remedy the trouble, but it can also be overcome by having gage glasses fitted to the evaporator coils or to a drain receptacle, into which the coil drain discharges, and keeping a water seal in this receptacle. As long as the water seal is maintained no steam can be blown through. To do this will require some care on the part of the attendant, but it can be done without serious difficulty. A large trap or a drain tank with an automatic float valve and fitted with a

gage glass could be used as the drain receptacle. Only one drain receptacle would be required for the entire plant. The essential point is to provide a water seal and to have a gage glass to show at all times that the water seal is there.

The heat contained in the coil drain from the H.P. evaporator can be utilized in a feed heater or run to the feed tank. If a vapor feed-water heater is fitted the coil-drain heater will not add much in economy, but it can be used to heat the evaporator feed above the temperature of the vapor supplied to the vapor-feed heater.

Losses Due to Blowing Down or Brining.—This loss is considerable and is one that can not be entirely eliminated. If a constant blow is used, the losses are quite indeterminate and, by carelessness, may become very great. If a constant blow is used it should be regulated by the saturation that is maintained. Three thirty-seconds is now considered the upper limit of saturation that should be used. If the saturation is maintained at this point by the constant use of the blow, the loss will not be materially greater than by periodically blowing down. If, however, a lower saturation is maintained there is considerably more loss.

The tube and water spaces of most of the evaporators used in the Navy are proportioned so that at their rated capacity the water is evaporated about once an hour. It is the usual practice to blow down once a watch. If this is done the saturation will be maintained at between $\frac{3}{32}$ and $\frac{4}{32}$. In blowing down, a great deal of heat may be wasted by having a high-water level before blowing. Just before blowing down the water level should be allowed to fall.

The amount of heat lost in blowing down can be approximated by calculation. Suppose the water capacity of evaporator is evaporated every hour and evaporator blown down every four hours. If there is one pound of water at 10 pounds pressure, the total heat of this water above 200 degrees F. will be 987. Evaporated four times this will be 3,948 B.t.u. In blowing down, water at 240 degrees is replaced by water at 60 or 70 degrees. This would account for a loss of

nearly 200 B.t.u. if no steam was blown out. In practice some steam usually is blown out. There is thus an unavoidable loss of about 5 per cent. due to blowing down, which loss in practice is probably increased several times. Waste of steam can be avoided by not blowing out all of the water. Most likely little attention is paid to this, and the evaporator man probably never thinks of it. Evaporator blows are frequently in a leaky condition, and possibly blowing down once a watch is too frequent. If the saturation is taken occasionally the proper frequency can readily be determined.

Losses Due to Priming.—Priming is a loss due to the fact that the salty water produced is wasted. Various devices have been introduced to effectively stop priming; the most important consists in fitting baffle plates above the nest of heating tubes. These baffles are usually galvanized-steel plates, and should be arranged so that the vapor in ascending must strike some part of the baffle. The baffle can be very simple and still be very effective. With baffles fitted, the water level in evaporator can be carried so as to almost cover the coils. Arrangement of successful baffles are shown in sketches.

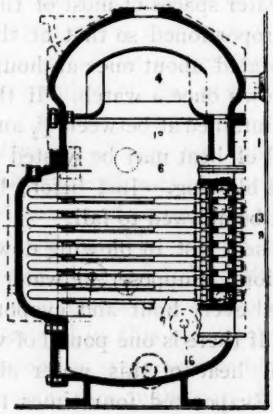


FIG. 1.—WEIR-EVAPORATOR WITH BAFFLE.

Separators should be fitted in the vapor lines to catch any water that may possibly get by the baffle. The separator drain should be led so that the water will drain back into the evaporator feed suction.

In order to detect priming it is well to lead the drains to a reservoir, which can be made of a piece of pipe having a gage glass on it. If the valve leading to the evaporator feed suction is closed, any priming will be indicated by the collection of water, and as long as no water collects no priming has occurred.

Separators may be built employing the principle of the De Lany separator or other generally accepted styles. The De Lany separator is thoroughly efficient and need not be as large as some of the other types.

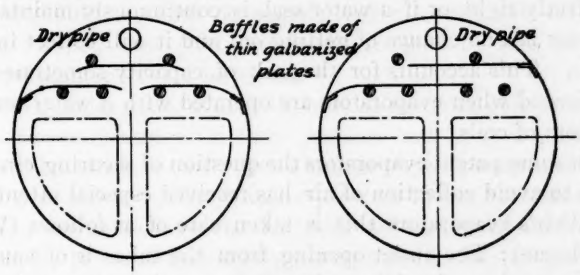


FIG. 2.—U. S. NAVY EVAPORATOR SHOWING POSITION OF BAFFLES.

A constant water level is another special aid to prevent priming. The water level should be carried so that a little of the coil-heating surface is above it, and acts to dry the vapor as it leaves the water. In order that a constant water level can be carried the feed should be continuous and the steam pressure constant. The special need of a good reducing valve is particularly felt. The evaporators can be operated without a reducing valve, but under these conditions the attendant is so busy regulating the steam pressure that he is unable to properly attend to other matters.

Superheaters.—Superheaters have been installed on some evaporators. These may be effective in drying the vapor, but

they are somewhat uneconomical. Efficient baffling in conjunction with separators in the steam line should render superheaters unnecessary. In cases where priming can not be overcome the use of one evaporator as a superheater has been resorted to.*

Air Collection in Coils.—The question of air collecting in some of the tubes surface should not be lost sight of. It may have a considerable effect in decreasing the capacity. It is important that a continuous current be maintained throughout all the tubes to prevent an air pocket being formed; furthermore, an air cock should be provided in the base of the coil or drain collector which will permit of air being blown out. Air will naturally collect immediately above the water level and it can be blown off at this point. If the trap is perfectly tight or if a water seal is continuously maintained the air has no chance of getting out and it will collect in the coils. This accounts for the lack of capacity sometimes experienced when evaporators are operated with a water seal in bottom of coils.

In some patent evaporators the question of securing circulation to avoid collection of air has received especial attention. In Weir's evaporators this is taken care of as follows (Weir catalogue): The outlet opening from the tubes is of smaller diameter than the inlet with the exception of that in the lowest or drain tube, which is the same area throughout, and through which any steam passing through the smaller outlets from the tubes is again returned through the evaporator along with the water of condensation and drained to hot well or feed tank. By this means the pressure in the stand-pipe

* The practice of using two evaporators in series, one being used as a superheater, has been developed in the destroyer flotilla. In this case live steam is admitted in the usual way to the coil of the evaporator that is used as a superheater, and the drain or outlet from this coil is led to the coil of the other evaporator, the drain from the second evaporator being led to a trap in the usual manner. The vapor made in the second evaporator is led to the shell of the evaporator used as a superheater through the blow or feed connection, and this vapor is dried or superheated by the live steam in the coil, thus thoroughly drying all moisture or priming that may have been carried over.

The second evaporator is operated at as high a capacity as possible without regard to whether it primes or not, since any water carried over will be taken out in the evaporator that is being used as a superheater. The pressure in the superheater evaporator is regulated by the valve in the vapor pipe. It is claimed that by operating the evaporators in this manner a capacity equal to the normal capacity of the evaporators is secured and by the use of the superheater all priming is avoided.

chamber at the outlet end is always lower than in the chamber at the inlet end, and a constant current is kept up through all of the tubes, thus preventing any accumulation of air and water.

Capacity of Evaporators.—Increased capacity is secured by increasing the pressure in the coils. With a higher steam pressure there is a greater temperature difference, and this will allow a greater evaporation per square foot of surface.

When coils are clean a much lower pressure will suffice than when heavy with scale. As coils become dirty increased pressure will have to be used to secure the same capacity. It is, however, deemed inadvisable to be continuously changing the reducing-valve pressure. It would appear better to keep a certain pressure which, in the double-effect plants in the Navy, should be about 60 pounds, and run with this all the time. When capacity is materially reduced by salt deposit the evaporator should be scaled.

When boiler steam is used there is no material gain in economy due to the use of a lower pressure and such a pressure should be carried as will give a proper vapor pressure in the L.P. evaporator. A high vapor pressure in the L.P. means a greater loss of heat in the distillers; on the other hand, it is generally believed that separators will not act properly where the vapor pressure is below the atmosphere. For this reason it appears advisable to keep the vapor pressure for L.P. evaporator at several pounds above the atmosphere. If, then, the vapor pressure in L.P. shell is kept at 5 pounds the vapor pressure and initial pressure in H.P. must be maintained at a point that will do this. The proper relation can be found by experiment. If all steam in coils is condensed the pressures should be approximately as follows:

H.P. coil, ...	50 pounds.
H.P. shell, ...	25 pounds.
L.P. coil, ...	20 pounds.
L.P. shell, ...	5 pounds.

The capacity can, of course, be increased by using higher pressures and by opening coil drains so as to permit more steam to pass through. This, however, is uneconomical.

To Find Fuel Consumption.—The amount of fuel used by an evaporating plant can be found approximately by shutting the plant down and noting the change in the amount of fuel used. This, of course, is not very accurate, but if observations are carefully and repeatedly made, it will serve to indicate approximately the quantity of that fuel the plant requires. The actual steam used can also be measured without much difficulty by allowing the evaporator drain to discharge into one feed tank on which everything else is closed off. An occasional test of this kind will show what the plant is actually doing, and if results are unsatisfactory a hunt for the trouble may be initiated. The performances mentioned at the beginning of these notes represent about the best practically possible, and if they are approximated it indicates a very efficient plant.

Scaling.—Evaporators should be scaled after 150–200 hours of actual operation. Some recommend scaling after only 100 hours of use. They should not be allowed to go more than 200 hours unless brining is extensively carried on or the water is less salty than ordinary sea water. The necessity for scaling will depend upon the nature of the water. Water in different localities differs considerably in its scale-forming properties.

Scale may be caused to remain soft by allowing the water and vapor to remain in the shell till immediately before the coils are withdrawn. In the presence of the vapor the scale is soft, but it becomes hard soon after being allowed to come in contact with air.

Corrosion of Interiors.—The interiors of evaporator shells are liable to serious corrosion. This usually is located slightly above the water line. The corrosion shows itself as a heavy, red rust, and in many cases the shell is corroded through in the course of two or three years.

The conditions found in an evaporator are such as will

stimulate corrosion. Sea water is evaporated at a high concentration; acids are present, and, furthermore, when salt water at a concentration above $\frac{4}{3\frac{1}{2}}$ is evaporated, hydrochloric acid, from the decomposition of magnesium chloride—which is very corrosive—is liberated in much greater proportion. Also sea water contains considerable air and some carbonic acid gas. This air when liberated furnishes oxygen, which in conjunction with the vapor furnishes all the elements necessary to set up serious rusting and pitting. Furthermore, we have steel and composition parts both subjected to the action of salt water.

About the only check to corrosive action supplied is the use of zincs. Though the zincs are eaten up and may check the corrosion to some extent, they certainly do not prevent it. Evaporator shells are sometimes galvanized on the inside. This lasts for a time, but the light coating of zinc is not durable.

The underwater parts of the shell are usually coated with a salt scale, and this usually protects the surface, and should not be removed in scaling unless it becomes unduly heavy.

The upper portions of the shell, however, have no scale protection, and this is where the corrosion is worse.

A coating of Portland cement has been used as a protecting covering and, when put on thin and caused to harden without cracks, will protect the metal. The coating should be renewed from time to time as it becomes damaged.

Before the cement wash is applied the shell should be scaled bare and then carefully and thoroughly wire brushed. The cement should be carefully screened before being mixed and should be absolutely free from lumps. The cement wash should be applied with a brush. After applying the wash the evaporator should be filled with water to cause the cement to harden properly.

The cement coating, under favorable conditions, will last for six months or a year.

The baffles which are usually made of thin sheet metal corrode quite rapidly, but they can usually be removed and re-

placed by the ship's force; but it is important to have the design so arranged that removal can be effected as easily as possible.

The formation of hydrochloric acid is much more active when the concentration is allowed to go above $\frac{4}{32}$ than when below this; hence it would appear that corrosion can to a considerable extent be checked by carefully avoiding a high saturation in the evaporator.

The question of whether *boiler compound* might be used has also been urged. This is no doubt impractical owing to the possibility of carrying over the soda which might contaminate the drinking water.

If all the parts of the evaporator were made of composition most or all of the corrosive action might be arrested.

IDEAL ARRANGEMENTS.

An ideal evaporating plant would, of course, be one in which the smallest possible amount of fuel is used and in which no great amount of weight is necessary and one that can be easily operated.

The greatest economy will be secured by operating on auxiliary exhaust steam, using a high multiple effect, and operating under a vacuum. Operating under a vacuum requires more care and attention than operating under a pressure.

Under port conditions on naval vessels there is not very much auxiliary exhaust available for evaporating. About the only exaust available is that from the feed, bilge and flushing pumps, and an occasional air compressor. It is estimated that on a large battleship not more than 3,000 pounds of auxiliary exhaust per hour are available. This supply, however, will in a quadruple-effect plant evaporate about 900 gallons of water per hour. This is about sufficient to supply the daily needs in port, so that the installation of a quadruple-effect plant operating on auxiliary exhaust is an entirely feasible matter. Should the auxiliary exhaust supply be deficient, additional live steam can, of course, be added.

"Lillie," apparatus on the *Dixie*, operating on auxiliary exhaust steam, produced over 3 pounds of water per pound of steam. It would appear entirely possible not only to operate the evaporating plant on the auxiliary exhaust, but at the same time keep up the temperature of the boiler feed by allowing all drains to discharge to the feed tank.

When underway there will on all occasions be plenty of auxiliary exhaust available, not only for evaporating but also for feed heating.

On a large ship an evaporating plant operated in quadruple effect on the auxiliary exhaust would result in a saving of about 5 tons of coal per day. This on large vessels is believed to be worth while. On small vessels, it does not appear to be desirable to install an elaborate plant utilizing the auxiliary exhaust which in any case is a rather small amount. If two evaporators are fitted, they should in all cases be arranged to operate in double effect, and vapor feed heaters should be supplied. This is now the practice on most naval vessels.

CORROSION OF COMMON METALS AND METHODS OF PREVENTION.

By Ensign S. J. Zeigler, Jr., U. S. N.

Paper read before the Student Officers, Post-Graduate Department, U. S. Naval Academy.

The damage done to the metal of ships' hulls and machinery by corrosion and the amount spent to prevent this damage is each year a large item of the total naval expenditure. This fact alone is enough to warrant our careful study of the cause of corrosion and of the means of preventing or checking it. Of the many theories advanced to account for corrosion, the following appear to be worth considering: the carbonic acid theory; the hydrogen peroxide theory; and the electrolytic theory.

For brevity we will consider corrosion of iron only. If carbonic acid, H_2CO_3, or a solution of CO_2 in water, which acts as an acid of the formula H_2CO_3 is allowed to react on iron, the following takes place:

$$2Fe + 2CO_2 + H_2O = 2FeCO_3 + 4H$$
$$2FeCO_3 + 4H + 3O = Fe_2O_3 + 2CO_2 + 2H_2O.$$

This reaction will continue as long as water, carbon dioxide and oxygen are present. These facts gave rise to the *carbonic acid theory*. However, iron will corrode when there is no CO_2 present, so we cannot say that the carbonic acid theory is the whole story.

The hydrogen peroxide theory explains corrosion in the absence of CO_2 by assuming that water, oxygen and iron give the following reaction:

$$2F_2 + 2H_2O + 4O = 2FeO + 2H_2O_2 = Fe_2O_3 + H_2O_2 + H_2O.$$

Experimental work gives this theory little corroboration, for H_2O_2 cannot be detected during ordinary corrosion. If it were present some of it would break down into water and oxygen. Hydrogen, and not oxygen, is liberated if corrosion is made to take place rapidly enough.

The theory that appears to hold good for all corrosion is *the electrolytic theory*. This theory is more complicated than the others, but up to this time, at least, it has not been disproved. It is assumed that when an electrolyte, an acid, base or salt is dissolved in water, the molecule of the electrolyte is dissociated into two or more ions. One of these ions is assumed to have a charge of positive electricity, and is called the cation, the other to have a negative charge, and is called the anion. Water itself is a weak electrolyte, and is slightly dissociated or ionized. It appears to be a weak acid.

The following are examples of ionization:

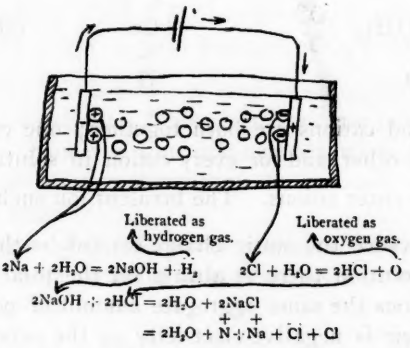
Molecules.	*Cations.*	*Anions.*
HCl,	$\overset{+}{H}$	$\overline{Cl}$
NaOH,	$\overset{+}{Na}$	$\overline{OH}$
NaCl,	$\overset{+}{Na}$	$\overline{Cl}$
H_2SO_4,	$\overset{+}{H}\ \overset{+}{H}$	$\overline{\overline{SO_4}}$
$Ca(OH)_2$,	$\overset{++}{Ca}$	$\overline{OH}\ \overline{OH}$
H_2O,	$\overset{+}{H}$	$\overline{OH}$

Anions and cations are born together; one cannot exist without the other, and for every cation in solution there is one or more sister anions. The bivalent ion such as $\overset{++}{Ca}$ or $\overline{\overline{SO_4}}$ carries twice the static charge carried by the univalent ion. In a solution there is always on the total number of existent cations the same aggregate amount of positive electricity as there is negative electricity on the existent anions. As soon as a cation gives up its charge and ceases to be a

cation, another cation must take its place or else an anion must give up its charge. That is, the positive and negative ions must be in equilibrium at all times.

It is in this way that a solution of an electrolyte is capable of conducting an electric current. Suppose the poles of a dry battery or any other source of an E.M.F. connected to two electrodes immersed in a solution of an electrolyte, NaCl for instance. The theory of electrolytic dissociation assumes that the NaCl molecule breaks down into ions of $\overset{+}{Na}$ and $\overline{Cl}$ as soon as the NaCl is dissolved. This condition is represented diagrammatically in the following figure. We conceive the cations and anions to be homogeneously distributed throughout the solution, so that there are in contact or near contact with the electrodes both anions and cations carrying their charges of positive and negative electricity. For simplicity suppose two sodium ions in contact with the negative electrode and two chlorine ions in contact with the positive electrode. The E.M.F. maintains a difference of potential between the electrodes. The two positive and the two negative ions give up the static charges, simultaneously becoming atoms, allowing a current to flow through the outside circuit.

The nascent sodium and chlorine atoms react on the surrounding water as indicated :



but as the NaCl is in solution it manifests itself as sodium and chlorine ions ready to supply the electrodes with more static electricity. As the current of electricity flows the amount of NaCl in solution remains the same, but the water is decomposed, passing off as oxygen and hydrogen gas.

Although ions of the same valency carry equal amounts of static electricity the potential of the charges on different ions is not the same. Every metal is somewhat soluble in water. Metallic potassium dissolves almost instantly, while gold is so slightly soluble that its solution can hardly be detected. The tendency of a metal to dissolve in water is called its solution tension. The following is a partial list of the metals in order of their solution tensions: potassium, sodium, aluminum, zinc, iron, nickel, tin, lead, hydrogen, copper, antimony, mercury, gold. The solution tension depends primarily upon the potentials of the ionic charge, and for any given pure metal varies: (1) with the temperature; (2) state of physical stress in exposed surface. For an impure metal or a non-homogeneous alloy the solution tension varies (3) with the nature of the impurities. This order of solution tensions of metals is also the order of their chemical activity. Any metal tends to precipitate any other metal of lower solution tension from a solution of its salt; that is, a metal tends to assume the ionic state at the expense of a metal of lower solution tension.

For any given temperature and concentration of a solution of an electrolyte there is a certain definite percentage of ions and molecules which is called the point of chemical equilibrium. The lower the concentration and the higher the temperature the greater will be the ionization. It has already been pointed out that there must exist ionic equilibrium; in order to introduce a cation into a solution either an anion must be introduced at the same time or another cation must be taken out. If a metal is immersed in an electrolyte whose cations are of a lower solution tension than the new metal, the new metal will throw off cations into the solution and the low-tension cations will give up their electric charges and plate out of the solution or be precipitated. As the

ionization in a metallic solution increases the tendency of that metal to dissolve in the solution decreases. This is called osmotic pressure of the solution. The osmotic pressure of a solution due to the metallic ions resists the entrance of more cations of that metal and also of any cations of a lower solution tension than the metal to which the pressure is due. The osmotic pressure of a solution and the solution tension of a metal immersed in it are opposed to each other, aud when they are balanced the metal cannot dissolve in that solution. The solution is saturated under these conditions. The electrolytic theory of corrosion assumes that corrosion is due entirely to: 1st, ionization of the metal, 2d, chemical action in the solution to precipitate the cations as oxides, etc. The rate at which a metal will corrode depends solely upon its rate of ionizing.*

Suppose a boiler tube and a zinc plate electrically connected immersed in an electrolyte. The zinc has the higher solution tension, its cations go into solution, cations from the solution plate out on the boiler tube and redissolve. The tube remains intact. In other words, we have formed a primary cell, the zinc furnishing the energy for the current. Soon the zinc plate becomes covered with a layer of zinc oxide. Zinc oxide has a lower solution tension than iron, and we would naturally suppose that as soon as this condition obtained the E.M.F. of the cell would be reversed. To quote Commander Lyon,† who experimented exhaustively on this very point, "A piece of zinc (rolled for boiler use) and a piece of American ingot iron, in one case, and steel, in another, connected by a copper wire, screwed hard into each, protected the iron and steel for four days; in distilled water by the end of seventeen days the protective effect of the zinc was entirely lost, and at the end of thirty days the steel and iron connected to the zinc had lost more per unit of area than similar pieces of the same irons and steels similarly connected to themselves in the same

* The foregoing is merely an attempt to state in a few words the essential ideas of the electrolytic theory of corrosion so masterfully presented in "Corrosion and Preservation of Iron and Steel," by Cushman and Gardner.

† "Transactions of the Society of Naval Architects and Marine Engineers," 1912, page 166.

water." From this it would appear that unless zincs are renewed at very frequent intervals, it is better not to use them in boilers at all. In the presence of bronze propellers zincs do appear to be of positive value, and waste away even under thick layers of oxide. Accurate and conclusive data on this point would be of great value.

Now assume the boiler tube alone immersed in an electrolyte. From point to point on the tube there will be small differences of solution tension due to local physical stresses and to impurities, such as scale, etc. At the points of high tension the iron will go into solution, cations from solution plate out, and current will flow from the points of low tension on the tube to the points of high tension, thus keeping up the action. No corrosion will take place at the points of low tension. Pits are points of high solution tension. From the foregoing it is inferred (and facts corroborate the inference) that to keep a metal from corroding, (1) it must be kept perfectly dry, by application of a waterproof protective coating; (2) the metal must be immersed in a liquid which does not dissociate, such as a pure hydrocarbon oil; or, (3) the osmotic pressure of the solution in which the metal is immersed must be kept higher than the solution tension of the metal at any point.

This last condition is the only method that can be used to prevent corrosion on the inside of boilers. Sodium carbonate Na_2CO_3, is found to be one of the best compounds with which to raise the osmotic pressure of boiler water. It is inexpensive, and sodium has the second highest solution tension of all the metals. The ordinary boiler compound issued to the service consists of about 95 per cent. sodium carbonate. The point of minimum Na_2CO_3 concentration at which iron will not corrode is determined by tests on specimens of the boiler tubes themselves placed in solutions of varying concentration.* The other constituents of boiler compound are merely to reduce surface tension of the water to prevent priming and to colloid the scale-forming constituents of the water, to prevent scale.

* A complete discussion of this can be found in "Naval Boilers," by Lyon and Hinds, in which Commander Lyon gives the results of many interesting experiments.

PROTECTIVE COATINGS.

The nature of a protective coating to be applied to iron or steel depends primarily upon the function of the object to be protected and the conditions to which it is to be subjected. It might be supposed that the first requirement of such a coating is impermeability. However, there are many other characteristics which must be taken into consideration. The following are a few desirable features in a protective coating. It should adhere firmly to the surface to which applied. It should cement itself together, and expand and contract without cracking. It should have a hard outer surface and be unaffected by sunshine, heat, cold, water and ordinary mechanical abrasion. It should inhibit corrosive action of traces of water under its surface and in contact with the metal. It should not disintegrate, but should wear gradually and evenly. No one coating so far available is perfect, and the best we can do is to select the coating which combines the most important features under the conditions of service.

There are three general classes of coatings available: (1) Magnetic oxide surface; (2) Plating with another metal; (3) paint, varnish, cement, or bitumastic coatings. If iron is heated to 900 degrees F. in a retort and superheated steam injected into the retort, the surface of the iron becomes covered with a thin layer of magnetic oxide. This, of course, renders the iron incorrodible so long as the oxide coating remains intact; but if at any point the coating became broken or removed in any way rapid corrosion ensues, as the rest of the iron oxide is strongly electronegative to iron. Iron may be plated or galvanized with zinc or plated with tin, copper, nickel, lead or other metal. Zinc is applied either by the hot-dip process, the electroplating process or the Sherardizing process, which consists of baking the objects to be plated in a retort with flaked zinc. Tin, though electronegative to iron, forms a coating which is practically incorridible. Tin plating is too expensive to be used extensively. Copper, nickel, lead and certain alloys also find their use as plating material.

By far the most commonly-employed protective coating is

paint. Paints may be divided into three general classes: (1) oil paints; (2) varnish or resin paints; (3) tar paints. For all round naval use oil paints are found to give the best result, though special paints are used extensively for ships' bottoms and in damp compartments. An oil paint is a pigment mixed and ground with oil, and the efficiency of the paint depends upon the characteristics of both binder and pigment. A good paint should be homogeneous, or as nearly so as possible, *i. e.*, the pigment should not settle quickly in the paint bucket; should work with little resistance to the brush, leaving a smooth covering of even thickness; should dry quickly and simultaneously throughout, and should not skin over. When dry it should present a surface to which another coat of the same or a different paint will adhere. In addition the dried coating should have as many as possible of the properties of the ideal metal covering already enumerated.

Linseed oil, either raw or boiled, has proved to be the best binder so far available. Linseed oil boiled properly is found to be a slightly better binder than raw oil, but paint makers do not advise the boiling of linseed oil by inexperienced persons. The quality of the oil affects the value of the paint more than any other factor. The "linseed oil" of commerce is often impure and of little value as a paint binder. A good "linseed oil is of a pale, yellow color, brilliant, limpid, drying well with a rich luster, and having a pleasant nutty taste." *

The pigments available for paint making may be divided into three classes, according to their effect upon corrosion: (1) inhibitors; (2) neutrals; (3) stimulators. The class of inhibitors includes willow charcoal, one grade of Prussian blue, zinc chromate, barium chromate, calcium chromate. Examples of stimulators are barium sulphate, some ochres, some red oxides, lampblack, graphite, and all carbons except willow charcoal. Some of the pigments which stimulate corrosion when applied to iron are excellent when used in paint for woodwork, etc. Pigments may also be classified according to whether they act chemically upon the oil or remain inert.

* Lowe, "Paints for steel structures."

The inerts form a paint which dries slowly, but which is of long life. Turpentine or other artificial driers may be used without detriment to the paint.

The conditions under which paint is applied and the method of application are further important factors in determining the resultant protective covering. The surface to be painted should be absolutely clean, bright and dry. The first coat should be applied with a full, round, bristle brush and the paint rubbed out and into the surface of the metal to displace the adhering film of gas. If it is possible to warm the metal surface to dry it, this should be done. If this is impossible the paint itself should be heated to about 150 degrees F. "It may be laid down as a normal standard that, presupposing the use of good paint, one bottoming coat and three subsequent coatings, laid on at suitable intervals, will be required to produce a layer of sufficient thickness on iron to keep moisture away from the metal and to protect the latter from rust for a certain time." * A permeability test which promises to be of great assistance to paint users has recently been devised.†

Red lead paint should be rubbed out as thin as possible, especially when applied to any other than horizontal surfaces, for the paint tends to run and thicken at obstructions, forming very thick layers which dry slowly and unevenly. Before a second coat is applied the surface of the first coat should be sponged off with a solution of brown soap and water. This gives a clean surface and one to which the next coat will adhere more firmly. In painting naked metal on board ships where it is impossible to heat the metal, much better results may be obtained if the paint is heated, and the metal surface sponged off with alcohol or gasoline. This sponging absorbs the water on the metal and quickly evaporates, leaving a dry surface. This also removes fine particles of rust, nearly always present on surfaces that have been chipped and wire brushed. These rust particles are particularly dangerous because they

* Andés "Iron Corrosion and Anti-Corrosive Paints."

† A. M. Muckenfuso before American Society for Testing Materials. (See Proceedings A. S. T. M., 1914.)

are hydroscopic. Painting over fine particles of rust saturated with water is one of the chief causes of the poor results obtained by scaling and painting done by ships' companies. The paints issued to the service for ship preservation are good, but the average bluejacket is a very poor painter and requires personal instruction and watching before good results can be obtained with the combination.

The paint for ships' bottoms in addition to providing a protective coating on the metal should prevent fouling or the attachment of barnacles and other small sea life to the ships' bottoms. It is put on in two distinct coatings, the first being the "Anti-corrosive" and the second coating embodying the "Anti-fouling" feature. The anti-fouling paint may contain a poison to kill the marine growth or it may attain its end by dropping off, carrying the foreign matter with it.

Bitumastic paints are now being used in the place of red lead in compartments protected from the weather, giving good results in trimming tanks, double bottoms, bilges, etc. A first coat or "solution" is put on thin, and a second coat of "enamel" or "cement" is put on about $\frac{1}{4}$ inch thick. This affords excellent protection for a long period of time. Its application or renewal should only be attempted by forces experienced in its use.

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U. S. S. *McDOUGAL.*

CONTRACT TRIAL PERFORMANCE.

By Henderson B. Gregory, Associate.

Torpedo boat destroyer No. 54, the *McDougal*, was authorized by an Act of Congress approved August 22, 1912, together with five other vessels of the same class. She was built under contract by the Bath Iron Works, Limited, of Bath, Maine. The contract was signed December 16, 1912, the price being $810,000, and the time of construction twenty-one months from date of contract. The designed speed was 30.5 knots, at about 1,025 tons displacement, with the main turbines developing 16,000 shaft horsepower.

The *McDougal* is a twin-screw vessel fitted with a combination of Parson's turbines and reciprocating cruising engine. The starboard shaft is driven by the main H.P. turbine, abaft of which and connected to the same shaft, is an independent astern turbine. On the port shaft is the combined L.P. ahead and astern turbine, just forward of which is the reciprocating cruising engine, fitted with disconnecting coupling for throwing out of gear when not in use. Steam is supplied by four oil-burning Normand water-tube boilers, arranged in pairs in two separate compartments.

The hull and machinery, except as noted below, are exact duplicates of the U. S. S. *Cassin* and U. S. S. *Cummings*, built by the same company, a description of which was published in the August, 1913, number of the Journal of the American Society of Naval Engineers, and which likewise applies to this vessel, except that the auxiliary condenser is increased to 284 square feet of cooling surface, and the generating sets are 25 kilowatts each, instead of 10 kilowatts as installed on the former vessels.

Principal Hull and Machinery Data.

Hull dimensions:

Length on L.W.L., feet and inches	300–00
over all, feet and inches	305–03
Breadth at L.W.L., feet and inches	30–03
Ratio, breadth to length (L.W.L.)	1 to 9.917
Draught to L.W.L., feet and inches	9–03
Displacement corresponding, tons	1,010
per inch at L.W.L., tons	14.25
Area immersed midship section, square feet	190
Coefficient of fineness, block	0.42

Main turbines:	Diameter of rotor drum, inches.	Length of rotor drum, inches.	Number of expansions.
M.H.P	46 to 48	132⅜	2 cruising, 6 main.
L.P	60	83 1⅝	6
Port astern	44	76½	6
Starboard astern	44	56⅜	6

R.P.M., designed	550
S.H.P., designed	16,000

Cruising engine:

Type	Vertical, inverted, direct-acting, compound, jacketed.
Cylinder, H.P., diameter, inches	16
L.P., diameter, inches	24
Stroke, inches	18
Crank set at, degrees	180
R.P.M. (corresponding to speed of 15½ to 16 knots)	270
I.H.P. (corresponding to speed of 15½ to 16 knots)	700

Main boilers:

Type	Normand water tube.
Number	4
Furnace volume (each), cubic feet	520
Number of smoke pipes	4
Area through each smoke pipe, square feet	19.2
$\frac{\text{Area through smoke pipe}}{\text{Furnace volume.}}$	0.0368
Heating surface (each boiler), square feet	5,375
$\frac{\text{Heating surface}}{\text{Furnace volume.}}$	10.34
Oil burners (each boiler), number	12
type	Modified Bu. of S.E.
Diameter, inches, tubes (outside)	1½ and 1¼
downcomers (inside)	10
steam drum (inside)	44
lower drums (inside)	19

TRIALS.

The contract required:

(*a*) A progressive trial over the measured-mile course at Rockland, Maine, for standardizing the screws, extending from maximum speed (at least 30.5 knots) down to a speed of 8 knots.

(*b*) A full-speed trial of four hours' duration in the open sea in deep water, at the highest speed attainable, the average for the four hours not to be less than 30.5 knots. The speed to be determined by the average revolutions of the main shafts, according to the official standardization curve.

(*c*) A fuel-oil and water-consumption trial of four hours' duration in the open sea in deep water, at an average uniform speed of 24 knots, as nearly as possible. The trial to be conducted as nearly as possible to service cruising conditions.

(*d*) A fuel-oil and water-consumption trial of four hours' duration at 15½ knots, under conditions similar to the preceding trial, but with the cruising engine connected and in use.

(*e*) An endurance trial of 10 hours' duration in the open sea at an average uniform speed of 15½ knots, as nearly as possible, following as closely as possible trial (*d*), with cruising engine connected and in use. Fuel oil and water consumption will not be measured on this trial, the purpose of which is to determine the reliability and endurance of the cruising engine.

(*f*) A fuel-oil and water-consumption trial of four hours' duration in the open sea, with the cruising engine connected and in use, at an average uniform speed of 12 knots, as nearly as possible.

(*g*) In addition to the above-enumerated trials the contract was amended to include a two-hours' trial at about 15½ knots, with the main turbines only in use, fuel oil and water consumption to be carefully measured on this trial.

Fuel-Oil Consumption Guarantees.—The contractors guaranteed that the fuel-oil consumption per knot run for all purposes, including that necessary for all auxiliaries in use on the trials, would not exceed 700 pounds at guaranteed maxi-

mum speed, 420 pounds at 24 knots, 167 pounds at 15½ knots, and 149 pounds at 12 knots, the consumption of the fuel oil at these speeds to be determined by the Trial Board from a curve based on the rate of fuel oil consumed on trials (*b*), (*c*), (*d*) and (*f*), and corrected to a standard of 19,500 B.t.u. per pound of fuel oil.

Standardization Trial (*a*).—This trial was conducted under favorable weather conditions, on May 12, 1914, on the measured-mile course off Rockland, Maine. In all 26 runs were made over the measured mile, at various speeds, and from the data obtained it was found to require 602.9 revolutions per minute of the propellers to attain the designed speed of 30.5 knots, 415.7 r.p.m. for 24 knots, 255.7 r.p.m. for 15½ knots and 195.5 r.p.m. for 12 knots.

Table I contains the data obtained on the various runs, from which the curves, Plate I were plotted.

TABLE I.

STANDARDIZATION TRIAL DATA - U.S.S. McDOUGAL - ROCKLAND, ME., MAY 12, 1914

No. of Run	Time on Course Mins.	Secs.	Speed in Knots	Revs. to go One Knot Star. Engine	Port Engine	Mean	R.P.M. Star. Engine	Port Engine	Mean	S.H.P. Star. Engine	Port Engine	Total
1	6	54.80	8.67	896.6	928.1	912.4	130.05	134.58	132.31	74	99	173
2	7	53.15	7.61	1034.4	1076.9	1055.7	131.17	136.57	133.87	83	93	176
3	6	54.82	8.68	911.3	941.5	926.4	131.81	136.17	133.99	91	93	184
Mean of Group			8.14						133.51			177
4	5	18.88	11.29	962.8	1052.1	1007.5	181.14	197.95	189.56	206	245	451
5	4	58.93	12.04	908.8	990.9	949.8	182.47	198.93	190.70	213	258	471
6	5	14.25	11.46	965.7	1045.3	1000.5	182.49	199.59	191.04	213	247	460
Mean of Group			11.71						190.50			463
7	3	43.40	16.11	936.5	1006.5	971.5	251.49	270.35	260.92	632	692	1324
8	3	55.66	15.28	976.8	1047.7	1012.3	248.65	266.69	257.67	581	676	1257
9	3	44.15	15.92	931.7	1005.0	968.4	247.11	266.55	256.83	623	676	1299
Mean of Group			15.65						258.27			1289
10	3	10.18	18.90	1066.1	968.9	1017.5	336.29	305.66	320.98	1720	907	2627
11	3	2.73	19.70	1031.2	945.8	988.5	338.61	310.57	324.59	1732	970	2702
12	3	6.92	19.26	1053.1	971.4	1012.3	338.07	311.83	324.95	1751	964	2715
Mean of Group			19.39						323.76			2687
13	2	29.07	24.14	1059.9	1023.1	1041.5	426.81	411.99	419.40	3666	2777	6443
14	2	28.12	24.30	1060.9	1026.6	1043.7	429.73	415.84	422.79	3610	2829	6439
15	2	28.48	24.24	1058.7	1029.6	1044.2	427.76	415.98	421.87	3674	2958	6632
Mean of Group			24.25						421.71			6488
16	2	11.38	27.40	1108.7	1099.9	1104.3	506.43	502.21	504.32	5693	5559	11252
17	2	11.17	27.44	1098.0	1083.3	1090.6	502.05	495.81	498.68	5644	5391	11035
18	2	12.22	27.28	1111.0	1100.5	1105.8	504.14	499.38	501.76	5699	5435	11134
Mean of Group			27.38						500.86			11187
19	1	56.97	30.93	1164.6	1185.3	1175.2	600.70	611.39	606.05	6981	8772	15753
20	1	58.83	30.29	1192.5	1211.7	1202.1	602.29	611.94	607.11	7122	8515	16237
21	1	56.27	30.96	1166.5	1184.6	1175.1	601.93	611.27	606.60	7756	8698	16451
Mean of Group			30.62						606.72			16340
22	1	56.12	31.00	1206.0	1269.2	1237.6	623.13	645.42	634.28	8187	9619	17806
23	1	57.25	32.07	1165.7	1206.9	1186.3	623.08	645.10	634.09	8106	9575	17681
24	1	56.48	30.91	1203.8	1256.7	1232.1	623.00	646.81	634.66	8106	9678	17779
25	1	57.33	32.04	1161.4	1200.1	1180.8	622.19	645.09	633.64	8135	9582	17719
26	1	55.80	31.09	1204.2	1254.0	1229.1	624.07	649.08	636.58	8081	9686	17767
Mean of Group			31.515						634.23			17741

ENGINE COMBINATIONS USED.- RUNS 1-6, RECIPROCATING ENGINE AND TURBINES; RUNS 7-18, TURBINES (STEAM ON H.P. CRUISING BELT); RUNS 19-26, TURBINES (STEAM ON MAIN BELT).

Four-Hours' 24-Knot Fuel-Oil and Water-Consumption Trial (*c*).—At 7:10 A. M., May 13, 1914, the trial was started. The weather conditions were only fair. A swell was running, which caused the vessel to roll and pitch considerably. The trial was run in the open sea off Monhegan Island and vicinity. The data obtained are given in Table II, column 4.

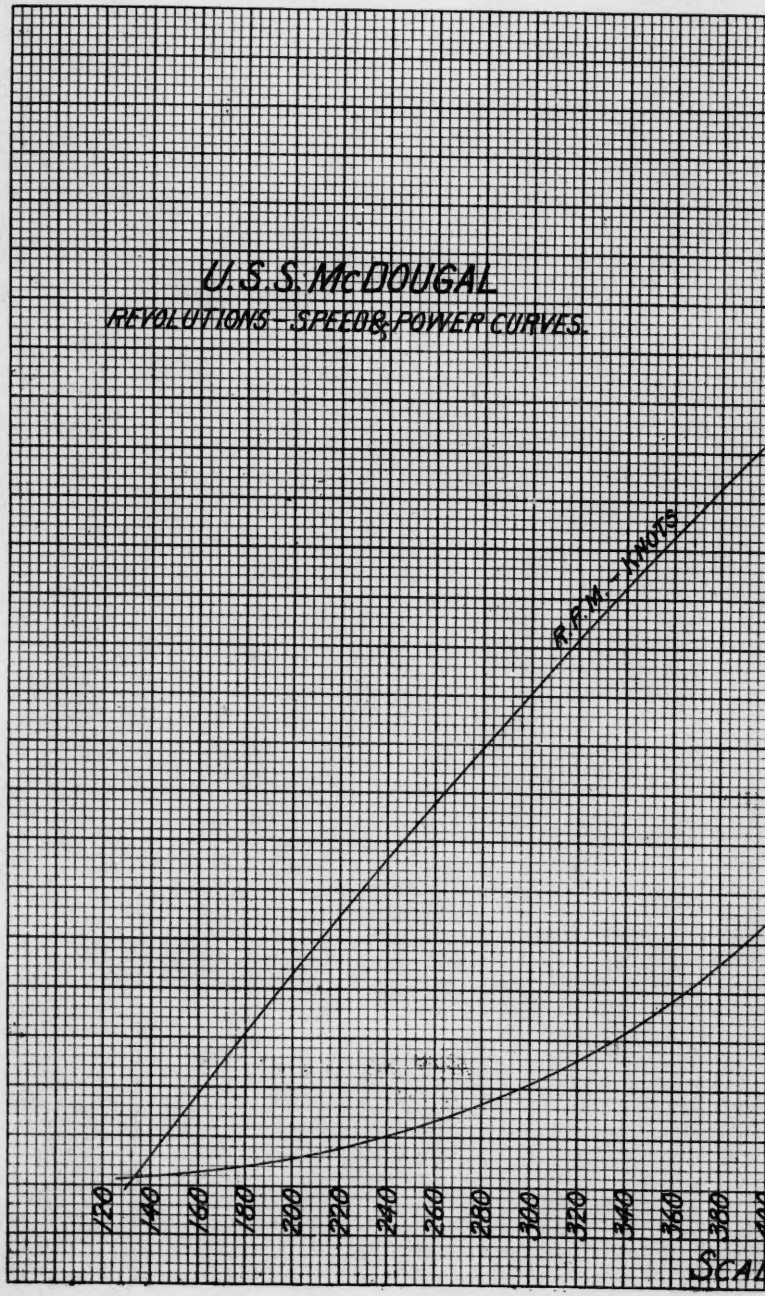
Four-Hours' 12-Knot Fuel-Oil and Water-Consumption Trial (*f*).—Following the 24-knot trial, the reciprocating engine was coupled up and the four-hours' 12-knot trial was begun at 1:05 P. M. on the same day, under good weather conditions and a smooth sea. For data see Table II, column 10.

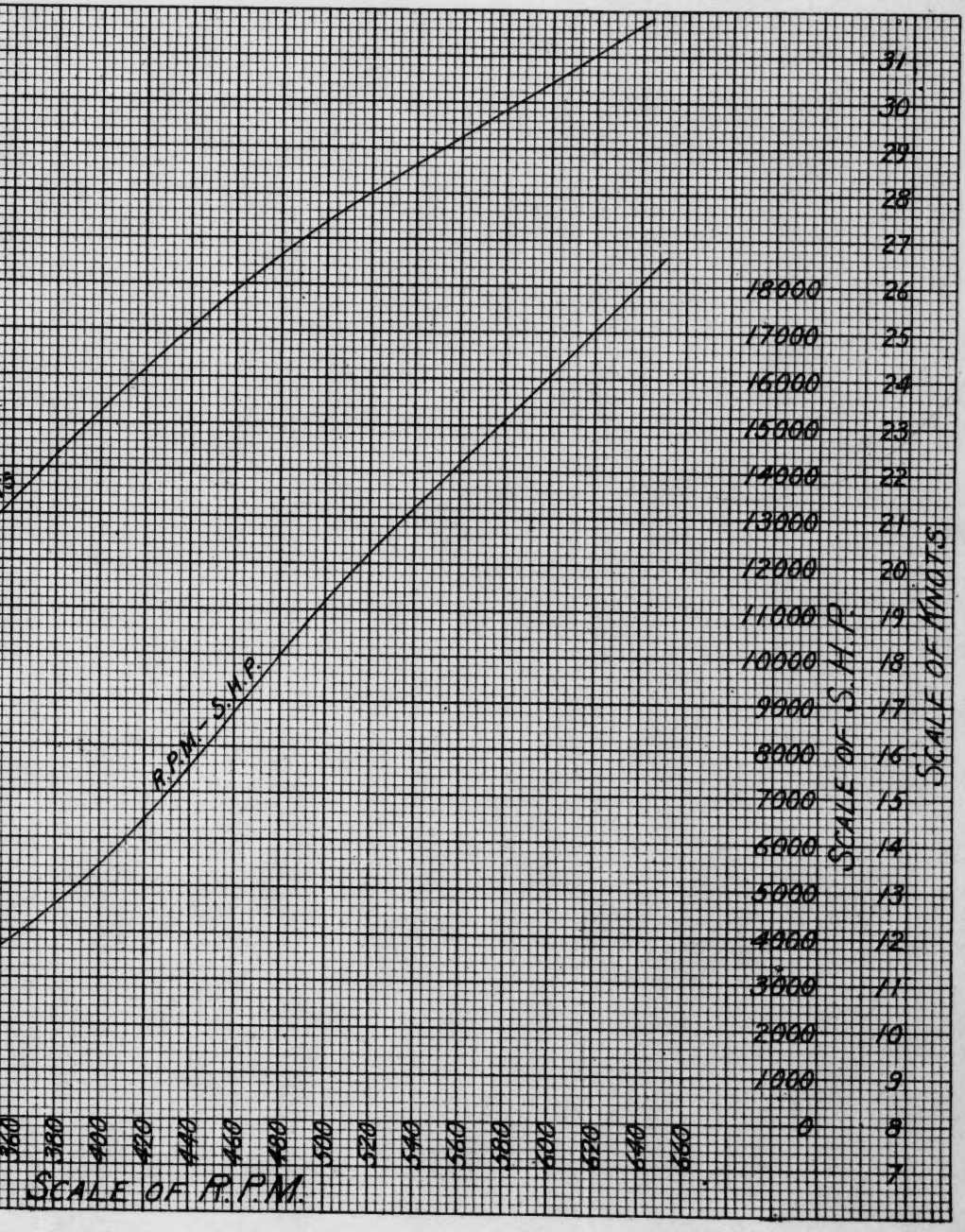
Four-Hours' Full-Speed Trial (*b*).—On the next morning, May 14, 1914, the full-speed trial was commenced, at 7:10 A. M., and was run in the general vicinity of the trials on the previous day. The weather conditions were generally favorable. During the trial the vessel rolled and pitched considerably. All guarantees were readily attained, as given in Table II, column 1.

Two-Hours' 15½-Knot Fuel-Oil and Water-Consumption Trial (*g*).—This trial followed the full-speed trial at 1:30 P. M. on the same day, and under generally similar weather conditions. The data for this trial are given in Table II, column 13.

Four-Hours' 15½-Knot Fuel-Oil and Water-Consumption Trial (*d*).—On completion of the two-hours' 15½-knot trial the cruising engine was again coupled up and the four-hours' 15½-knot trial was started at 3:45 P. M. on the same afternoon. The weather conditions were very good, with light swell running. For data see Table II, column 7.

Ten-Hours' 15½-Knot Endurance Trial (*e*).—This trial was commenced at 9:07 P. M., May 14, 1914, off Portland, the vessel standing on various courses, and was successfully concluded at 7:07 A. M., May 15, 1914, off the mouth of the Kennebec River. The weather conditions were very good. The average revolutions per minute during this trial were


U.S.S. McDOUGAL
REVOLUTIONS - SPEEDS & POWER CURVES.
R.P.M. - KNOTS
120
140
160
180
200
220
240
260
280
300
320
340
360
380
SCALE


R.P.M.-S.H.P.
SCALE OF R.P.M.
SCALE OF S.H.P.
SCALE OF KNOTS.
18000
17000
16000
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12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
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PLATE I.

TA

TRIAL DATA – U.S.S. McDOUGAL – ALSO THE COMPARATIVE DATA OF

	4-HRS. FULL POWER TRIAL (b)			4-HRS. 2
	McDOUGAL	CASSIN	CUMMINGS	McDOUGAL
	1	2	3	4
DATE OF TRIAL	MAY 14, 1914	JUNE 26, 1913	AUG. 27, 1913	MAY 13, 1914
SPEED IN KNOTS	30.697	30.137	30.574	29.074
DRAUGHT, MEAN ON TRIAL, FEET AND INCHES	9-3 11/16	9-3 1/4	9-3 1/4	9-3 11/16
DISPLACEMENT, CORRESPONDING, TONS	1021	1011	1014.5	1013.4
SLIP OF PROPELLERS, PER CENT., STARB'D.	22.27	22.54	22.68	13.96
PORT	24.46	25.15	26.31	10.60
ENGINES IN OPERATION	H.P. & L.P. TURBINES, STEAM ON MAIN BELT			H.P. & L.P. TUR
NUMBER OF BOILERS USED	4	4	4	4
BURNERS USED (12 PER BOILER)	48	46	48	20.7
HEATING SURFACE USED, SQ. FT.	21500	21500	21500	21500
SQ. FT. PER S.H.P.	1.267	1.405	1.316	3.353
COOLING SURFACE SQ. FT. (MAIN COND.) PER S.H.P.	0.636	0.706	0.661	1.684
PRESSURES (AVERAGE):				
MAIN STEAM, AT BOILERS, POUNDS GAUGE	256.4	256	257.5	240.2
ENG. ROOM, " "	247.9	244.4	244.6	240
MAIN H.P. BELT, ABSOLUTE	248.3	245.2	251.1	104.7
H.P. CRUISING BELT, ABSOLUTE	250.4	—	248.4	196.2
H.P. 2ND EXPANSION, "	195.3	168.2	175.6	73.9
H.P. 6TH " "	31.8	31.9	33.5	14.25
L.P. AHEAD, ABSOLUTE	21.91	21.2	22.7	11
L.P. 2ND EXPANSION, ABSOLUTE	14.76	13.8	13.75	6.03
GLAND STEAM, POUNDS GAUGE	0.5	1.44	−0.07	0.78
H.P. VALVE CHEST, RECR ENG., POUNDS GAUGE	—	—	—	—
L.P. RECEIVER, " " , " ABS.	—	—	—	—
L.P. EXHAUST, " " , " ABS.	—	—	—	—
VACUUM, MAIN COND., INCHES OF MERCURY	28.85	27.8	28.48	28.78
BAROMETER, INCHES OF MERCURY	30.08	30.22	29.95	30.12
AUXILIARY STEAM, POUNDS GAUGE	249.3	252.1	246.9	239.8
EXHAUST, " "	5.34	5.44	0.57	5
MAIN FEED, AT PUMPS, " "	300	298.4	345	300
FORCED LUBRICATION, " "	26.3	24	20	21.3
FUEL OIL, POUNDS GAUGE	256.6	146.1	220.45	134.7
AIR PRESSURE IN FIRE ROOMS, INCHES OF WATER	5.73	6.08	6.25	2.92
REVOLUTIONS OR DOUBLE STROKES PER MIN. (AVERAGE):				
STARB'D. SHAFT	600.25	591.97	602.01	425.23
PORT "	617.63	612.59	630.56	409.44
MEAN	608.99	602.28	615.79	417.27
MAIN AIR PUMPS	(2) 24.8	(2) 37.7	(2) 23	(2) 18.65
FEED PUMPS	(2) 23.5	(2) 25.15	(2) 23.9	(1) 21.6
FORCED DRAFT BLOWERS	(4) 1350	(4) 1437.4	(4) 1516.75	(4) 890.95
FUEL OIL SERVICE PUMPS	(2) 45.3	(2) 21.1	(2) 17.2	(2) 20
SHAFT HORSE POWER (AVERAGE):				
STARB'D. SHAFT	7963	7077	7519	3622
PORT "	9011	8230	8816	2791
TOTAL	16974	15307	16335	6413
TEMPERATURES, DEGREES F (AVERAGE):				
MAIN AIR PUMP DISCHARGE	57.1	70.2	77.9	73.4
INJECTION	43.4	55.1	60.8	43.1
OUTBOARD DELIVERY	72.9	81.9	88	75.6
OUTSIDE AIR	48	56.8	74	48
ENGINE ROOM	84.6	—	95	81
AUXILIARY ROOM	58.6	—	76	59
FIRE ROOMS	100.5	95.65	110.4	88.3
FEED WATER	193.7	170.7	180.1	189.9
FUEL OIL TO HEATERS	51.5	65.4	70.6	58.7
BURNERS	155.9	66.9	167.9	67.8
SMOKE PIPES	790.6	777.2	690	500.15
WATER CONSUMPTION:				
POUNDS PER HR., MEASURED	246293.75	229127	240038.25	108009.2
RESERVE FEED	1439.25	0	0	1383.2
TOTAL EVAPORATED	247733	229127	240038.25	109392.4
PER S.H.P.	14.51	14.97	14.69	16.8
EVAPD. PER SQ. FT. OF H.S.	11.52	10.66	11.16	5.0
LB. OF OIL	12.27	12.63	13.22	13.8
KNOT RUN	8070.33	7603	7851	4544
FUEL OIL CONSUMPTION:				
B.T.U. PER POUND	19396	19300	19452	19396
SP. G. AT 60° F.	0.8817	0.8775	0.878	0.881
POUNDS PER HOUR	20195.4	18138.84	18156.51	7914.8
KNOT RUN	657.89	601.88	593.85	328.7
AT	305 645 HRS. 700	29 342.5 HRS. 680	29 522 HRS. 680	24 325 HRS. 420
GUARANTEED, AT	55	137.5	158	95
BELOW GUARANTEE	1.190	1.185	1.112	1.23
HOUR PER S.H.P.	0.939	0.844	0.845	0.36
SQ. FT. OF H.S.				

NOTE.- FIGURES IN BRACKETS ( ) INDICATE NUMBER OF AUXILIARIES IN OPERATION.

TABLE II.

DATA OF HER TWO SISTER-SHIPS, U.S.S. CASSIN AND U.S.S. CUMMINGS.

	4-HRS. 24-KNOT TRIAL (c)			4-HRS. 15½-KNOT TRIAL (d)			4-HRS. 12-KNOT TRIAL (f)			2-HRS. 15½ KT. TRIAL (g)
	McDOUGAL	CASSIN	CUMMINGS	McDOUGAL	CASSIN	CUMMINGS	McDOUGAL	CASSIN	CUMMINGS	McDOUGAL
	4	5	6	7	8	9	10	11	12	13
	MAY 13, 1914	JUNE 25, 1913	AUG. 27, 1913	MAY 14, 1914	JUNE 27, 1913	AUG. 28, 1913	MAY 13, 1914	JUNE 25, 1913	AUG. 28, 1913	MAY 14, 1914
	24.074	24.048	23.991	15.55	15.522	15.47	12.033	11.999	11.946	15.506
	9 - 3 13/16	9 - 3 ½	9 - 4 ¼	9 - 3 ⅞	9 - 4	9 - 4 1/16	9 - 3 ⅞	9 - 3 ⅜	9 - 5 ¼	——
	1013.4	1015.5	1024	1019	1022.5	1022.8	1020	1030	1030	——
	13.96	14.79	14.81	2.96	5.81	3.13	0.01	4.22	- 0.25	10.62
	10.60	11.82	11.89	12.49	11.97	12.74	12.57	10.51	14.15	4.81
	H.P. & L.P. TURBINES, STEAM ON H.P.C. BELT			CRUISING ENGINE, H.P. & L.P. TURBINES			CRUISING ENGINE, H.P. & L.P. TURBINES			AS TRIAL (c)
	4	4	4	1	1	1	1	1	1	2
	20.7	21	18.5	6	6	6	4.75	4	4	7
	21500	21500	21500	5375	5375	5375	5375	5375	5375	10750
	3.353	3.387	3.425	4.349	4.427	4.005	10.397	14.449	8.642	8.175
	1.684	1.701	1.721	8.738	8.896	8.048	2.089	2.903	1.736	8.213
	240.2	238.2	204.9	249.1	218.63	223.5	204.4	210.2	180.6	201.3
	240	231	202	240	207.5	220.6	200	205.1	170.6	207.4
	104.7	106.6	106.6	——	22.5	16.4	——	16	15	27.6
	196.2	200	193.2	39.8	45.8	34.7	20.9	15	15	61.4
	73.9	70.5	67.8	18	18.6	14.8	10.8	14.1	7.8	22.9
	14.25	——	13.1	3.88	4.25	2.4	2.81	2.88	1.9	4.64
	11	10.2	9	3	3.1	2.25	2.5	2	1.5	3.5
	6.03	5.5	6.16	1.5	1.9	2.09	1.63	1.56	1.37	1.5
	0.78	1.5	0	0.5	1.5	0.5	0.5	1.5	0.31	0.78
	——	——	——	210.5	197.4	205.9	130.4	94.8	115.6	——
	——	——	——	110.1	101.5	104.7	71.5	47.5	56.9	——
	——	——	——	46.8	48.5	46.4	29.6	18.62	20.1	——
	28.78	28.4	29.1	27.8	27.6	27.8	27.09	27.6	27.8	29.6
	30.12	30.16	29.95	30	29.73	29.9	30.12	30.18	30.03	30
	239.8	237.8	202	239.1	212.6	225.2	199.5	210	179.5	209.5
	5	5.8	3.8	3.4	5	5.9	5.8	2.75	6.4	5.6
	300	290	343.8	300	279.4	337.5	300	293.8	237.5	290
	21.3	26	15	19.8	22.9	15	19.5	14.4	12.5	19
	134.7	150	155.7	146.3	132.5	144.4	117.5	150	96.8	137.5
	2.92	384	4.2	2.88	4.43	3.43	2.18	3.8	2.05	2.29
	425.23	429.35	428.04	243.56	250.74	242.71	182.24	190.61	181.12	263.66
	409.44	414.95	413.86	269.34	268.29	269.44	208.67	204	211.5	247.58
	417.27	422.15	420.95	256.45	259.52	256.07	195.45	197.31	196.31	255.63
	(2) 18.65	(1) 30	(2) 15.9	(1) 24	(1) 36	(1) 15.4	(1) 10.9	(1) 19.3	(1) 12	(1) 15.4
	(1) 21.6	(2) 10.1	(2) 12	(1) 8.1	(1) 7.75	(1) 8	(1) 5.4	(1) 7.1	(1) 5	(1) 10.8
	(4) 890.95	(4) 1224.1	(4) 1032.75	(2) 848	(2) 1217.5	(2) 965	(2) 710	(2) 1158.8	(2) 736.4	(2) 798
	(2) 20	(2) 9.6	(2) 11.7	(1) 14	(1) 6	(1) 6	(1) 11	(1) 4.3	(1) 5.1	(1) 16
	3622	3620	3378	471	540	463	183	183	138	761
	2791	2728	2899	765	674	879	334	189	484	554
	6413	6348	6277	1236	1214	1342	517	372	622	1315
	73.4	66.5	79.8	58.5	66.4	71.2	55.5	62.8	69.2	67.1
	43.1	54.1	39.1	46	56	60.9	42.9	53.1	58.9	43.9
	75.6	80.8	74	68.8	81	89	73.8	80.8	90	67.4
	48	57.6	70	52	56.1	68	46	57.3	70	52
	81	——	92.7	78.9	——	73.8	75.1	——	99.8	78.4
	59	——	74	59.3	——	78	60.1	——	82.5	59.4
	88.3	93.7	100.5	96	92.9	96.4	79.3	80.6	88.4	95.3
	189.9	197.1	202.3	222	221	225.7	228.8	215	230.5	227
	58.7	67.1	72.9	59	70.5	73.3	55.6	70	73.2	58
	67.8	153.2	73.6	66	73.8	72.9	75	72.9	74.5	64.3
	500.15	591.25	497.1	581.3	610	548.7	446.2	550	410	451.85
	108009.25	104693	109779.75	32704.5	32059	33458.75	21987	21096	19783.35	41372
	1383.25	1092	756	1192.75	2968	1708	1624	1134	879.25	698.5
	109392.5	105785	110535.75	33897.25	35027	35166.75	23611	22230	20662.6	42070.5
	16.84	16.49	17.49	26.46	26.41	24.93	42.53	56.71	31.81	31.46
	5.088	4.920	5.141	6.306	6.517	6.343	4.393	4.136	3.844	3.914
	13.82	13.34	13.95	14.72	14.26	15.02	15.18	13.77	15.52	14.89
	4544	4399	4607.33	2179.85	2256.58	2273.21	1962.18	1852.67	1729.65	2713.19
	19396	19300	19452	19396	19300	19452	19396	19300	19452	19396
	0.8817	0.8775	0.878	0.8817	0.8775	0.878	0.8817	0.8775	0.878	0.8817
	7914.8	7928.86	7921.93	2303.1	2455.64	2341.73	1553.9	1614.62	1331.57	2824.8
	328.77	329.71	330.2	148.11	158.2	151.37	129.63	134.56	110.63	182.17
	24 {325 KTS. 420	24 {328 KTS. 420	24 {330.5 KTS. 420	15.5 {148 KTS. 167	15.5 {157 KTS. 205	15.5 {151.5 KTS. 205	12 {129.6 KTS. 149	12 {135 KTS. 165	12 {112 KTS. 165	15.5 KTS. 182
	95	92	89.5	19	48	53.5	19.4	30	53	——
	1.234	1.249	1.262	1.863	2.023	1.745	3.009	4.340	2.141	2.148
	0.368	0.369	0.368	0.428	0.457	0.436	0.289	0.300	0.248	0.263

256.35, corresponding to a speed of 15.56 knots. No other data were taken.

As a matter of interest and ready reference, corresponding data, not heretofore published, from the trials of the U. S. S. *Cassin* and U. S. S. *Cummings* (sisterships of the *McDougal*) are also given in Table II, columns 2, 3, 5, 6, 8, 9, 11 and 12.

SOME PHENOMENA OF RADIO TELEGRAPHY,

WITH NOTES ON OBSERVATIONS MADE AT THE GOVERNMENT RADIO STATION, RADIO (ARLINGTON), VA.

By Ensign Harold E. Saunders, U. S. Navy, Member.

With the rapid extension and development of wireless telegraphy, in the short space of fifteen years since Marconi's first successful experiments, there has appeared in the world of science an almost unknown physical force, which is destined to play no little part in the future development of civilization. In fact, so rapid has been the adoption of this new method of telegraphy that scientists and investigators have not been able to keep pace with the radio engineers. These latter, in their haste to erect stations and install outfits, have not taken the trouble to find out the why and the wherefore, the electrical phenomena and the physical laws which create the conditions that they take for granted. This is but reasonable, when we consider that the science of radio telegraphy, marvelous as it may seem, is still in its infancy, and that it has a future far greater than its history in the past. We are not surprised to find, therefore, that the procedure has been the same as though we had been dealing with the electric current some fifty or one hundred years ago. We have had to use the results of experiments in order to deduce laws which would suit the existing conditions, then set forth theories which would fit the facts, and explain the conditions. With these laws and theories at hand, we are now to develop further uses of this wonderful force, and perhaps to express, in concrete form, some such ideas as gave us the electric generator and the incandescent lamp. It is the purpose of this paper, assuming that the fundamental principles are understood, to state some of the extraordinary and curious phenomena which have been

observed as the result of some two years of tests at the Arlington Station, and to show how this information has been applied to new theories and the ideas incorporated in new designs. We shall confine ourselves to external phenomena only, and omit all discussion of spark gaps, high voltages, resonance and high-frequency currents, as being quite sufficient to warrant a separate paper.

In order better to understand the conditions, let us go back to the pioneer radio installation. The original antenna used by Marconi consisted of a single wire suspended from the top of a very high mast, which mast was erected upon the highest hill in sight. This idea was to get the wire as high up into the air as possible in order to counteract the effect of the curvature of the earth, just as if the signals were to travel in a more or less straight line from the top of one wire to the top of the other. After realizing that the greatest practicable height of mast did not give the radiation and the working radius that he desired and thought possible, Marconi devised the scheme of suspending a number of vertical wires from one or more masts, whence came the fan-shaped, funnel, and umbrella-type antennas. Further work along this line showed him that the more wires were suspended in the air the more radiation and the greater radius were obtained, the limit being reached when all the wires were stretched horizontally and parallel to each other at the maximum height, with but a single wire to carry the current up to the antenna. Thus was developed the flat-top antenna (now extensively used for the Marconi plants and for stations of our own Radio Service), whose efficiency depends upon the fact that the working radius varies as the height of the center of capacity of the aerial, and not as the height of the loftiest wire. Taking it for granted that the wave radiates from the capacity—the set of parallel wires—we thus obtain not only a long wave but a high one, sufficiently large to pass by irregularities on the surface of the earth without being appreciably distorted.

For this reason the antenna at Arlington was designed to consist of three sets of parallel wires (each set 300 feet long),

forming the three sides of an equilateral triangle. One vertex is carried by a tower 600 feet high, and the other two vertices by towers 450 feet high, so that the average height of the capacity, practically all of which is concentrated in these wires, is about 500 feet. The new Government Station in the Canal Zone, Panama, will be a still further improvement, in that it will have a triangular aerial as above, but 900 feet on a side, each vertex to be carried by a steel tower 600 feet high. This large capacity and high aerial should give a radiation and a working radius which will far exceed that of any other station of equal rated power.

Here, however, we come upon another factor of transmission efficiency, which caused no little concern among radio engineers until they realized its full importance. We refer to the "ground" of a set—an element which is quite as important a part of the system as the antenna itself. To illustrate, let us see what happened at Arlington. At the time the station was built the only site available was a small plot of ground on the top of a hill some 200 feet high, and here the towers were erected. The "ground" was constructed in the usual manner, by burying a network of wires in the soil underneath the antenna and by connecting these wires with the grounded side of the set in the power house. Here, however, it was impossible to get the damp earth, such as the directions call for when burying the end of a lightning rod, for no sooner had the soil become wet than all the water drained off down the hill and left it as dry as before. Additional wires were laid, deeper than the others, yet the earth connection seemed to be no better. It was still very noticeable that, all other things considered, signals came in much stronger on wet and rainy days when the soil was moist and the ground connection practically perfect. This is one reason, no doubt, why the Arlington Station has not been an unqualified success; had it been built down alongside a marsh, in damp ground, as was suggested at one time, it is thought that much more consistent results would have been found, even though the antenna would have lost about 150 feet of its absolute height thereby.

Very wisely, therefore, are the engineers building the new Panama station; it is built on islands, directly over Gatun Lake, so that there should be no trouble about keeping its "ground" moist.

Apropos of the failure of the Arlington Station to come up to expectations, we shall bring in a third factor of transmission efficiency, the geographical location of the station. It is a well-known fact that as good, if not better, results are obtained from the Key West Government Station (35 kw.) as from this station (Arlington, 70 kw.), which can be due only to the fact that the former station is surrounded by large bodies of water on all sides. Just why Hertzian waves should travel with less loss of energy over water than over land is one of the "whys" which may never be explained. That this is so, however, can hardly be doubted, for signals from Key West, coming over the Gulf of Mexico and over the low Mississippi Valley to stations as far north as Minnesota and the Dakotas, are received with considerably greater intensity and much greater reliability than those which are sent out from Arlington, even though the latter start from a closer source and with about twice the radiation power. No doubt the existence of the Appalachian range has something to do with this strange state of affairs, yet the decreased absorption over water is everywhere so marked as to leave little doubt of the influence of a low river valley, lake or ocean. It is for this reason, and also because the ship's structure forms such an excellent ground, that vessels are able to work their radio equipment to such advantage. It is often the case that their receiving power is as great as that of a much larger land station, for cases are on recrod where men-of-war at Key West have heard Mare Island, California, and in Mexican waters have received press news from the North Atlantic coast. What we believe to be the most extraordinary case on record is the reception of signals from the (Sayville) Station on Long Island by the U. S. S. *Florida,* when lying in the harbor of Naples, Italy, in the fall of 1913. Still more remarkable results are looked for from the new Panama Station. The sit-

uation there is ideal, with large bodies of water on all sides, such as to give an almost complete ocean-surface path to any adjacent part of the continent.

Leaving aside peculiarities which are perhaps true of one station only, we find a far greater class of phenomena which pertain to radio emissions in general. By far the most important of these is a peculiar property of the ether through which these waves are supposed to be propagated, a property which expresses itself as a greatly reduced absorption power of the medium for night transmission. Tests have been made to show that the loss of energy decreases rapidly within so short a time as one-half hour after sunset, a fact which goes to show that sunlight has an appreciable effect upon the other medium with which we are concerned. Whether this increased absorption by day is due to ionization or dissociation of the medium by the radiant heat of the sun is another question still unanswered. We are led to suppose, however, that ether, which is not of the nature of a material substance, undergoes changes in itself and in its properties exactly as do water or air or other substances with which we are familiar.

Nor does this decrease of absorption decrease with the establishment of absolute darkness. It continues with a lowering of temperature, so that on very cold nights the energy transmitted is relatively so great that we might imagine a second night had come. This was very forcibly illustrated during the past winter, when some trans-Atlantic tests were being made. About the second week in January, when the temperature on the east coast of North America, over the North Atlantic, and on the Atlantic coast of Europe, were in the neighborhood of about 10 degrees F., signals were received with a loudness which had never before been recorded. Two complete messages, one of which was in cipher, were received at the Eiffel Tower in Paris from the 35 kw. station at Key West, over 4,000 miles away, a performance that would never be possible under ordinary conditions. So great an effect does this temperature have upon the transmitted energy, that we can very accurately predict the intensity of the

received signals by a few minutes' study of the temperatures on a weather map. And it is not unreasonable to suppose that, if we were to reduce the temperature of our atmosphere to the neighborhood of absolute zero, we should find only that inappreciable loss of radiant energy which exists in the intervening mediums between the sun and the earth.

We must, however, reconcile this absorption theory with another, which has to do with transmission of signals at night, that the greater part of the night radiation is carried by its waves through the ether in the vicinity of the upper strata of the atmosphere, while the waves which carry the energy in the daytime travel along the surface of the earth. These "day waves" seem to stick to the surface as if they were lines of force attracted by the magnetic effect of the earth, with the result that they come into collision with hills, mountains and other irregular masses which project from the level surface of the globe. This impact tends to distort the waves, so that if they are short, and if they meet many obstacles, they are soon broken up and their fundamental wave motion thrown into violent confusion. Long waves, however, seem to be able to pass over mountains and hills and other disturbing influences without losing their essential form, and it is for this reason that very long lengths, 3,500 to 7,000 meters, have to be employed for long-distance work in daylight.

No such disturbing conditions exist at night, however, with the wave-length path in the homogeneous ether of the upper atmosphere. With this state of affairs we obtain the best results by using a wave just long enough to retain its shape after the necessary amount of absorption has taken place—about 2,500 meters for general work, increasing to 4,000 for the Marconi trans-Atlantic wireless service between Clifden and Glace Bay.

This transmission of energy in the upper atmosphere is one of the most important phases of radio science today, and the one concerning which we know the very least. It is only by assuming this hypothesis, however, that we are able to explain some very interesting phenomena, and, by working with

it as a basis, that we can hope to increase the present efficiency of the system.

In the first place, it is very often noted that at night the signals from a far-away station will die out within the short space of a half hour or so, or that they will be very loud for a number of nights, and then, without any warning or any reason whatsoever, a night comes when not one is heard. An investigation of the weather map again will probably show that at the time in question there was an area of low barometric pressure, accompanied by the usual electrical strain in the atmosphere moving between the two stations. This electrical disturbance, which may or may not result in a thunder storm, very likely has a damping effect on the waves, or it may be that the electrical tension of the atmosphere and ether forms a barrier to deflect the oncoming vibrations; in any case, violent irregularities occur in the transmission, which might very readily be caused by these cloud-like disturbances, or barriers, between areas of high and low barometric pressure.

Secondly, it has been found, after a series of tests conducted during the past winter between the Arlington Station and the Eiffel Tower, that the apparent speed of the Hertzian waves between these two places is less than it should be, by about 6,000 miles per second, or three per cent. We assume, of course, that in the theoretically perfect condition these waves travel with the same velocity as those of light, 186,400 miles per second, and in a direct line from point to point. A decrease of three per cent., therefore, in the absolute or standard speed, shows that this transmission must take place under extraordinary conditions. We find that the speed of waves of visible light in the ether of space is identically the same as in the ether of the earth's atmosphere, so we are led to suppose that the same holds true for Hertzian waves. We look, then, for a more plausible solution, and this is briefly as follows: That the waves do not travel in a great circle course directly from one point to the other; that they not only are deviated from a straight course by areas of electric tension, such as were spoken of above, but that they travel upwards

to a great height and take other devious courses in the high strata of the atmosphere. Certain it is that they travel in nothing like a straight line, even when the distances are short, as a direct result of the non-homogeneity of the medium.

The question then arises: If these ether vibrations, or whatever we choose to call or imagine them, ascend to a height of 15 to 20 miles, how do they descend to the earth's surface, so as to produce currents in the receiving antenna? This is reasonably explained by a third line of argument, recently advanced by Dr. L. W. Austin, of the Bureau of Standards, and now generally accepted among radio experts.

To understand this most peculiar of radio phenomena a word is necessary concerning the working principle of the Poulsen arc, or continuous-oscillation type of the spark systems. To make the dots and dashes, essential to every type of telegraphic communication, the wave length of these continuous waves is changed by the key from 3,900 to 4,100 meters, say, and the receiving set is so sharply tuned that it will respond to the 3,900-meter waves and not to the longer waves, or it may be set to respond to the 4,100-meter waves, at the expense of the shorter ones. In any case, if signals were being made with the 3,900-meter wave, one operator listening on that wave length would get the proper message, while another operator listening on 4,100 would get an unintelligible confusion of dashes and dots, really the intervals between the signals being received by the first operator. Now if these operators notice that their signals seem to be growing weaker, with apparently the same sensitiveness of the receiver, they make some pre-arranged sign and switch over to the other wave length, say, 4,100. Nine times out of ten they will find that the 4,100-meter signals come in as loud, if not louder, than the shorter waves did at first, and they continue to send until such time as they may have to shift back again.

This phenomenon is explained by Dr. Austin, who states that of these night signals, part of the radiation travels, like day signals, along the surface of the earth, and part in the upper regions of the atmosphere. Those waves which ascend

to the upper strata strike a layer or surface between the medium next to the earth and the ether beyond in space, are totally reflected, as from a mirror, and descend to earth in much the same manner as they ascended. Arriving at a point on the surface near the receiving station, they meet, and may be in phase with, the vibrations which have traveled along the surface, in which case the signals will be intensified. If the mirror-like cloud takes upon itself to ascend or descend, as it may do in the short space of a few minutes, the waves become completely out of phase (due to the lengthening or shortening of the path of the reflected ray), and interfere with each other in such a manner that the signals almost disappear. When this happens the two operators shift to the other wave length; the new length of the reflected wave path will be an integral number of wave lengths greater than the path of the direct wave, the two will reinforce each other, and the signals be heard with as great intensity as before.

It is with such a set as just described, of only 30 kw. rated output, that night signals have been sent from Washington to Honolulu, a distance of 5,100 miles, and it is to this system of continuous wave oscillation that we must look for hitherto unheard-of developments in the realm of radio science.

NOTES ON AEROPLANE STABILIZATION.

By William L. Cathcart, Member.

The necessity for stabilizing the aeroplane needs no proof. The born aviators—men with an instinctive sense of equilibrium—are very few. The hundreds who make flights now and the thousands who will make them in the future, if they shall use unstabilized machines, will either risk their lives by slow and inept handling of the controls or, in an extended flight, will yield to fatigue produced by the nervous strain of constantly restoring to its balance a machine which is normally in indifferent equilibrium. The task of directing fitly the flight of such an aeroplane in uncertain air is comparable in some respects with that of steering a bicycle at high speed over a rough road in darkness or fog, since the ordinary aviator loses to some extent this sense of inclination, of the angle of his flight. The necessity for relief from this ceaseless mental and nervous strain is especially pressing with the military or naval aviator, whose flights in reconnoissance are likely to be of long duration with the added hazard of attack. Whether acting as observer, pilot or, in emergency, as both, all that is possible should be done to conserve his energies for the military purposes of his mission.

The aviator can be freed from all work except that of steering the machine—as he would a motor boat—in either of two ways: by so constructing the aeroplane that it has great inherent stability and will right itself when its equilibrium is disturbed, or by placing the ailerons and elevating plane under automatic control for the same purpose. Consider first

INHERENT STABILITY.

The ordinary aeroplane is purposely unstable, so that it shall yield instantly to the aviator's control. Considered as a pendulum, its centers of gravity and suspension almost coin-

cide. As a result, when flying in rough air, it tends to oscillate about its center of gravity, both in its course and longitudinally, and to slip or drift sideways under the blast of a lateral gust. Longitudinal oscillations will act to make it dive, an effect which is aggravated by the shifting aft in diving of the center of pressure of the wings. The purpose of inherent stability is to correct, so far as is possible, these dangerous tendencies by suitable relations, in area and location, of the parts exposed to abnormal wind pressure when the machine oscillates or slips.

When the aeroplane heels in sidewise slip there is a resisting wind pressure on all lateral surfaces, and, if the aggregate moment of those surfaces above the center of gravity be greater than that of those below it, there will be a resultant righting moment which will restore equilibrium. Again, to prevent oscillations in its course from lateral wind pressure, the moment of all lateral surfaces thus under pressure and forward of the center of gravity must be equal to that of those aft and under similar pressure, so that the machine shall not spin around that center. If the stern moment is permitted to be the greater, the machine will tend thus to spin and, as a consequence, to dive. The longitudinal oscillations, which act also to produce diving, are damped and forced to die out by suitably proportioning—as to area and location—the fixed tail whose pressure has a righting moment in a vertical plane. These, in brief, are the main principles of designing for inherent stability; they have been applied with more or less success, especially in British military aeroplanes.

There are serious disadvantages in the operation of an aeroplane thus stabilized. In the first place, since a righting moment can be generated only by a previous movement of the machine, the latter is, in rough air, continually rolling and pitching, to the discomfort of the aviator. Again, as its inherent stability gives the machine itself much of its own control, it is sluggish and reluctant in responding to the aviator's sudden call, thus making it difficult to handle and dangerous in descent and landing. A rough analogy to its general action

in troubled air is that of a flat-bottomed scow, afloat in a moderate sea. With its relatively great metacentric height the scow is amply stable, but it rolls and pitches ceaselessly and steering is most difficult. With regard to the possible danger in landing with a sluggish stabilized machine, Major H. Bannerman-Phillips writes in the "Scientific American":

"It must be remembered that the self-balancing aeroplane, so-called, whether it owes its steadiness and stability to design and construction, as in the Dunne machines, or to automatic control, as when fitted with the Doutre stabilizers, has the defects of its self-righted qualities in that, when the pilot does exercise full control, as, for instance, in turning or landing, it is apt to be sluggish in answering to that control, which, under certain circumstances, may be awkward and even dangerous. For instance, at maneuvers in Great Britain quite recently, an officer of the Royal Flying Corps who had chosen his landing place and was coming down, suddenly became aware of a squadron of cavalry which, in the course of a sham fight, was emerging from cover and charging across the open ground he had selected. By a supreme effort of skill and judgment he managed to avoid them, but one shudders to think of the havoc his machine would have caused if, through want of skill on his part or slowness of the aeroplane in answering to the controls, it had been driven among men and horses."

AUTOMATIC STABILIZATION.

From the number of factors which enter it is evident that the automatic stabilization of an aeroplane is a complex problem. It has attracted a number of inventors, but the really practical attempts at solution have been few. On June 18 a Safety Contest was held on the Seine between Bezons and Argenteuil, near Paris, before a board of judges appointed by the Aero Club of France. There were 72 contestants, and but two prizes were awarded. The Sperry gyroscopic stabilizer won the first prize of $10,000 offered by the French War Department. But one other entrant, the Doutre automatic stabilizer, received a prize. Its stabilization is, it is

claimed, not universally effective. In any event, the results of this contest show that the Sperry apparatus represents thus far the most successful solution of this problem.

The details of the Sperry mechanism have not been made public. The general principles of its design and operation are as follows: The stabilizer was installed in a Curtiss flying boat of the ordinary type. It is very compact, weighing but 45 pounds, and was located beneath the hood in the bows of the boat. It can be connected or disconnected by light pressure on a pedal, so that the aviator can resign or resume instantly his full control of the machine. This ready disengagement removes the objection advanced by Major Bannerman-Phillips to permanently stabilized machines of any type, as being unresponsive in times of sudden danger. The rudder is always under control of the aviator, although it can be locked in position for straight flight. In automatic stabilizing the movements of the elevating plane and ailerons are governed by four gyroscopic discs, each weighing one kilogram and each revolving at 12,000 turns per minute, within a casing in which a vacuum is maintained in order to eliminate the friction of the air.

The principle which is utilized for automatic control is that when a gyroscopic disc is rotated at high speed with its axle in a horizontal plane it will oppose the tilting of the axle from that plane with a resistance whose limit is the gyroscopic moment. Evidently, then, the axle of such a disc, if swung in a gimbal mounting like a ship's compass, will provide a horizontal reference plane in space, and any deviation from the vertical by the fork or frame supporting the gimbal ring (which frame is fixed to the hull of the flying boat) will produce relative motion between the frame and ring. The motion is utilized, as in the " follow-up" mechanism of the gyroscopic compass, to operate electric trolley contacts capable of engaging stationary contacts through which servo-motors are started and stopped. These motors actuate either the elevator, the ailerons, or both, until the deviation from the vertical is corrected. The function of the discs is therefore simply to indi-

cate the character and amount of the motion which is required, while the servo-motors do the actual work of righting the aeroplane. It will be observed that this analysis refers only to the broad principles involved and does not consider the details of the mechanism. It relates also to horizontal flight only.

A single disc, as described above, cannot be used, because it would be pendulous and, hence, affected by accelerating pressures and centrifugal force. Two discs, coupled, would obviate these actions, but soon a pair would serve to maintain the stability of only one axle, and, for complete stabilization, both longitudinal and transverse deviations must be corrected. Apparently for this reason four discs are employed, presumably coupled in pairs with the units of each pair precessing in different directions, one pair operating the ailerons, the other the elevating plane. These discs coöperate to produce a horizontal reference plane in space, so that any deviation, laterally or longitudinally, from the horizontal by the aeroplane when in horizontal flight will be corrected in its inception, without the aviator's action or knowledge.

Between the reference plane and each servo-motor there is placed a floating lever which permits any desired inclination of the aeroplane, longitudinally or laterally, without derangement of that plane. To effect inclined flight under automatic governing the floating lever of the elevator control has connections which can be set at the proper angle by hand, so that, after the gyroscopes have thus been given the required angle of inclination of the aeroplane, they will maintain automatically that angle in flight until the connection is changed. If the aeroplane engine breaks down, the angular momentum of the gyroscopic discs is sufficient to keep them running for half an hour, giving the aviator ample time for descent. Further, when, through engine failure, the speed of flight falls to the critical point, a device governed by an anemometer starts the machine volplaning gently to the earth at an angle of about 20 degrees.

The tests at Bezons were severe. Setting his longitudinal control for ascent, the aviator rose from the Seine, standing

upright with arms upraised to show that he was touching no controls. When an altitude of about 600 feet was reached, he adjusted the stabilizer for horizontal flight and, again standing erect, went to and fro over the course in an undeviating line, stooping only to steer the machine around at each end. Finally, standing thus with no hand on any lever or wheel, he sent his mechanician out for about six feet on the lower plane. The man's weight at that distance from the center of gravity of the machine produced an overturning moment of about 1,000 pound-feet, but the aeroplane flew along at 60 miles an hour in undisturbed equilibrium. The explanation was that, as the mechanician increased his distance from the center, the angle at which the ailerons met the air was augmented, gradually and automatically, in order to compensate for the overturning moment; when he returned, the ailerons resumed, again gradually and automatically, their normal position. This test demonstrated lateral stability. To prove longitudinal stability, the mechanician crawled out on the lower plane as far as possible toward the propeller. This traverse produced a longitudinal overturning moment of about 700 pound-feet, but again the eqilibrium of the machine was undisturbed since the elevator was moved gradually and automatically to compensate for the magnitude of moment at each instant, as the ailerons had been previously. These tests were repeated some days later for French and Russian naval aviators.

With the swift march of invention other methods of stabilization will doubtless be developed. Meanwhile, the gyroscope seems to have provided a means to that end which is instant and powerful in its action and will reduce to a minimum the nervous strain and resultant fatigue of the aviator. For example, in sweeping around in a curve he will no longer have to move simultaneously the rudder, elevator and ailerons, but will simply steer, while the gyroscopes, at any instant, will be insensibly swinging the aeroplane around a resultant axis due to the momentary composition of the rotations about its lateral and longitudinal axes and that of the curve. Graphic records show also that stabilizing increases markedly the accuracy of

straight flight, since the hand-controlled machine must deviate considerably, laterally or longitudinally, before the ordinary aviator is aware, and, when he is conscious of it, his tendency is to make an over-correction. As a result, his course is perceptibly zigzagged or corrugated, while that of the stabilized machine is practically straight, since the gyroscopes stop deviation at its beginning. M. René Quinton, President of the National Aerial League of France, who made a trial flight at Bezons in rough air, states in "Le Matin": "These tests have given us a new self-governing aeroplane, which ascends, navigates, descends, and responds to every gust and eddy, constantly reëstablishing its disturbed equilibrium without the aid of man."

NOTES ON SUBMARINE REPAIRS AND OPERATION.

By Lieutenant C. N. Hinkamp, U. S. Navy, Member.

Repairs at sea on submarines are the best type of quick repairs which the service has presented in the past few years. The gasoline engines were of a type which were inherently troublesome, and even after extensive tests prior to runs, which tests showed up well, the engines would break down in the most unusual manner and at the most inopportune times. An incident is recalled where the bed plate of the engine broke immediately under the main bearing, destroying the support of the crankshaft at this point. The parts of the bed plate were set in place, a small screw jack was put under the broken shell, and the entire water-jacket space was filled with cement and sand, thus making a concrete main-bearing support. The lower brass was put in place on this cement foundation, scraped to a fit, and after allowing the cement to harden for an hour or so, the engine was started and ran successfully for the entire season.

During a 50-hour run one of the cylinders in one of the boats broke circumferentially in such a manner as to disable the engine completely; that is, the cooling water overflowed into the boat through the break, instead of overboard. This engine was converted into a five-cylinder unit in the following manner: All the damaged parts were removed, which consisted of the cylinder head and the upper half of the cylinder, and all the valve mechanism for that cylinder. The piston and connecting rod were removed. The water-jacket space was plugged with wooden wedges, cotton waste, old dungarees, paper, and firmly tamped down on top of this was a layer of cement. All water-pipe connections that were broken

were plugged with wooden plugs. The exhaust and induction pipes for that cylinder were blank-flanged. The engine was tested with water pressure, found tight, and started up. This repair took about two and a half hours, was made while the other engine was running, and was made by one machinist's mate and a gunner's mate to help him. The engine ran successfully on five cylinders for over twenty-four hours, or until the end of the run, when permanent repairs were made.

OBSERVATIONS ON THE VARYING DENSITY OF WATER.

The difference in density of the waters of Chesapeake Bay as compared with those of the Atlantic Ocean is quite marked. This is shown in the quantity of ballast necessary to trim a submarine. An actual experience may illustrate the case in point. In the summer of 1912 the submarines of the Third Division maneuvered in the lower bay, where they conducted drills submerged, fired torpedoes and held engine runs. In one run the boats submerged off Cherrystone Light and headed for the open sea. The trim was easily maintained and no trouble was experienced for the first five miles, after which there was a noticeable difference in the handling of the vessel, all indications pointing to a condition known as "light." Water to the extent of about 500 pounds was added and for a few miles all went well, when another 400 pounds had to be added to keep the boat level. This continued, and as the entrance to the Bay was reached still more water had to be added. When finally the open sea was reached it was found that over 2,000 pounds additional ballast had been added over that in the boat when originally trimmed. This was due to the increasing density of the water as the sea was reached. On the return trip it was necessary to remove ballast to the extent of about 150 to 200 pounds every mile or so in order to maintain normal positive buoyancy, as the boat gradually became "heavy" as progress up the Bay was made.

In a static dive, where no headway is made, the boat can be balanced to such a nicety that the variation in depth for several minutes is almost nothing. While making such a dive

off Annapolis it was discovered that balancing at various depths was comparatively easy and that the boat floated with periscopes just exposed with no variation in depth. The 100 pounds of water were added, which under ordinary circumstances would cause the boat to sink to the bottom, but the boat sank about 15 feet and held her depth after a few oscillations. More water was added and, after sinking about 20 feet more, the boat remained at a constant depth. This was repeated until the depth of seventy feet was reached and the boat rested on the bottom. The above experience demonstrates that the density of the waters in Chesapeake Bay vary in considerable amounts as the depth increases, and clearly shows that strata of water exist as well as strata of earth. The existence of these strata of water of varying densities may account for the large number of torpedoes lost in this vicinity, which after a run would sink with a small amount of negative buoyancy in the water near the surface, and striking the heavier strata would float off, rendering useless the markings made by the crews of the boats where the torpedo was last seen.

INTER-SHIP COMMUNICATION BY SUBMARINE SIGNALLING.

By William L. Cathcart, Member.

Note.—This is a second article on the subject of Submarine Signalling and presents a viewpoint of an engineer interested in the development of new and novel engineering apparatus. In this article special comment is made of the Fessenden Oscillator and various interesting phenomena connected with its use. This article taken in connection with that of Lieutenant Carter in this number gives a general survey of the whole question of Submarine Signalling.—H. C. D.

The field of submarine signalling is as wide as the oceans of the world and as the shores which bound them, for it is the unseen at sea which the sailor dreads more than the wildest fury of winds or waves. Much has been done for his protection from invisible dangers. Rarely now, except in unsurveyed waters, is the submerged rock reported, the derelict floating awash is systematically hunted down in the paths of commerce, and, since the loss of the *Titanic,* the Ice Patrol gives timely warning of icebergs in the steamer lanes. But, there remains the ocean fog which—sweeping down suddenly as a *bouchon de brume* or "fog plug," or resting for days like a cloud of cotton wool on the surface of the sea—shuts in the ship, veiling her impenetrably from the sun and stars and the lights of other vessels, and making ever imminent the danger of collision or of running ashore.

Many millions have been expended on lighthouses, lightships, buoys and aerial fog signals; but, except for the as yet relatively limited application of submarine signalling apparatus, the ships of commerce—triumphs of science in their construction, carrying sometimes millions of dollars worth of cargo, and always a far more precious human freight—are still subjected, often for weeks at a time, to the deadly dangers of

the fog, especially in such crowded waters as those of the English Channel, the North Sea, the Great Banks, and our New England coast. The sea's history in recent years, as the fleets of commerce have grown, shows many a tragedy from this cause, like those of the blind and blundering *Monroe* and *Nantucket* and the swift destruction of the *Empress of Ireland*. In its hazard thus of life and property, the neglect of provision for defence from fog has been mediaeval, as if science and invention were still in the long slumber of the Dark Ages.

AERIAL FOG SIGNALS.

The roar of the fog-horn, the boom of the fog-gun, and the shriek of the siren count for little, as every seaman knows, in giving the direction of their source, and indeed they may be wholly misleading, for, when all is said, these sounds are primarily but waves in the air, the most inconstant medium we know. Blown by cross-currents, subjected to reflection or refraction in meeting dense or rarified strata, their sound, like the wind which bears it, "bloweth where it listeth" and we "cannot tell whence it cometh." Its source may be miles away, or, if it be deflected by currents, the ship may be steaming through a zone of silence straight toward the ledge, shoal, or rock-bound coast from which it comes. Again, while wireless telegraphy with its S. O. S. call has been a mighty agent in the salvation of ships in distress, it is, although ethereal, affected by atmospheric conditions; it gives at best but an approximate position for a ship sinking swiftly in a fog, and that position, it found by dead reckoning, may be far from accurate. It is true that a radio-goniometer has been devised for determining the bearings of a vessel which is sending out radio signals, but, even if serviceable in favoring conditions, the efficiency of the apparatus is still affected by atmospheric changes.

SOUND WAVES IN WATER.

The characteristics of water as a means of propagating sound waves meet fully the objections to aerial signals. It is a uniform medium, and sound vibrations in such a medium

travel in straight lines without reflection, refraction, or zones of silence, so that the direction of their source can be determined with accuracy. Again, although water is virtually incompressible and relatively great force is required to produce compressional waves of sound in it, its absorptive power is much less than that of air, and hence the vibrations diminish but slowly in intensity and the sound can be transmitted much farther than through air. The speed of signalling is also greater, since sound waves traverse water more than four times as fast as air. Finally, the deflecting winds which make the air siren powerless to aid and the atmospheric disturbances which affect wireless telegraphy have no effect on sound waves in water. Submarine signalling thus provides a means of nullifying wholly the dangers of fog.

SUBMARINE SIGNALLING IN NAVAL WARFARE.

In addition to its service in fighting fog, submarine signalling has unquestionably a field of the widest possibilities in naval warfare. With the Fessenden oscillator, under-water telephoning seems now wholly practicable for distances of five miles or more, and telegraphic signals by the Morse code have been received from a source 25 knots or about 30 land miles away. The advantage to the flag officer of a fleet in action, in being able thus to communicate instantly and invisibly with any of his ships, is of great importance. No single factor could do more to make a fleet a readily handled and quickly responsive unit in battle.

Further, the possibility that the submarine boat may soon develop into a submarine cruiser seems far from remote, and no one can safely predict the stage to which that development may attain or its effect on the sea fighting of the future. But a year ago, Mr. Winston Churchill, First Lord of the British Admiralty, stated in Parliament that " the strength of navies cannot be reckoned only in Dreadnoughts, and the day may come when it may not be reckoned in Dreadnoughts at all." Recently, Admiral Sir Percy Scott startled the naval world by declaring that the Dreadnought's day was done, that " sub-

marines and aeroplanes have entirely revolutionized naval warfare. No fleet can hide itself from the aeroplane eye, and the submarine can deliver a deadly attack even in broad daylight." The success of submarines in all recent maneuvers convinces him that no coast protected fully by them can be bombarded, blockaded, or invaded by troops convoyed by battleships, and, conversely, no battleship fleet defending such a coast can resist submarine attack. That the battleship has no longer a reason for existence and that the submarine will dominate the seas, are the Admiral's conclusions.

He has met the customary fate of the prophet, false or true. Lord Sydenham's cynical comment—"A fantastic dream"—probably represents the consensus of authoritative naval opinion with regard to this prediction as to the untimely fate of the capital ship of today. Nevertheless, the progress and success of the submarine boat, especially within the last two years, cannot be ignored. Hitherto, the defective action of the magnetic needle within its crowded hull has restricted it to coast service, but the perfection of the gyroscopic compass now opens the Seven Seas to it. If a system of under-water propulsion, less cumbrous and heavy than storage batteries, can be devised for it, its entry as a cruiser in the high seas will be assured. The British Admiralty is said to be developing the "boats" of the past into submarine vessels of about 1,500 tons displacement, and our Congress recently authorized a sea-going submarine which will have a surface speed of 20 knots and a consequent displacement of at least 1,200 tons.

With any extended development in submarine warfare, the effective application of submarine signalling is linked indissolubly. It gives the only means by which, when submerged, courses can be set or changed or firing orders given by the admiral of the fleet or the commander of the submarine division, and hence its use will provide the only way in which a concerted and precise attack in force will be possible. The bells and receivers now carried by our submarines fulfil this mission to a limited extent. Under-water telephoning, however, would widen this service immeasurably. Five miles or

more away, the flagship of the fleet or the flagboat of the division could maneuver that division at will in approach, attack, and withdrawal.

THE SUBMARINE BELL.

Submarine bells have been used as coast warning signals for about fourteen years on lightships, buoys, and pierheads. The system is gradually becoming world-wide, bells having been installed at 174 points on the Atlantic and Pacific coasts of North America, on the shores of the Great Lakes, of Great Britain, and the Continent of Europe. Bells sending out a sound of about 1,200 virbrations per second, and therefore of high pitch, have been selected for this purpose because this sound is distinctive, as compared with the foreign noises of low pitch—such as that made by water rushing past the ship and that due to the vibrations of the hull and machinery—with which it must contend.

The sound-receiving apparatus of the Submarine Signal Company consists of two iron tanks bolted to the skin of the ship, one on each bow, each filled with salt water, and each having a microphone suspended in it. The microphones are connected with the pilot house or chart room by an electric telephone system. The compressional waves of sound radiating from the bell impinge on the skin of the ship, which acts virtually as a diaphragm and transmits them, without diminution of their intensity, to the water in the tanks inside. When, by trial changes of course, both microphones are made to register a sound of the same strength, the ship is headed directly toward the bell. About 1,225 ships are now equipped with this apparatus.

THE FESSENDEN OSCILLATOR.

Bells are used successfully for signalling between submarine boats, and in such service as that of the tenders at Cherbourg, which during a fog guide the liners into the harbor like sheep following a bellwether. From a ship moving slowly in a fog an emergency bell can also be lowered from a davit and rung

by hand-power to indicate her position. In general, however, the bell is not a satisfactory means of sending out signals from a ship steaming at fair speed and inter-ship communication by it is not practicable in average conditions.

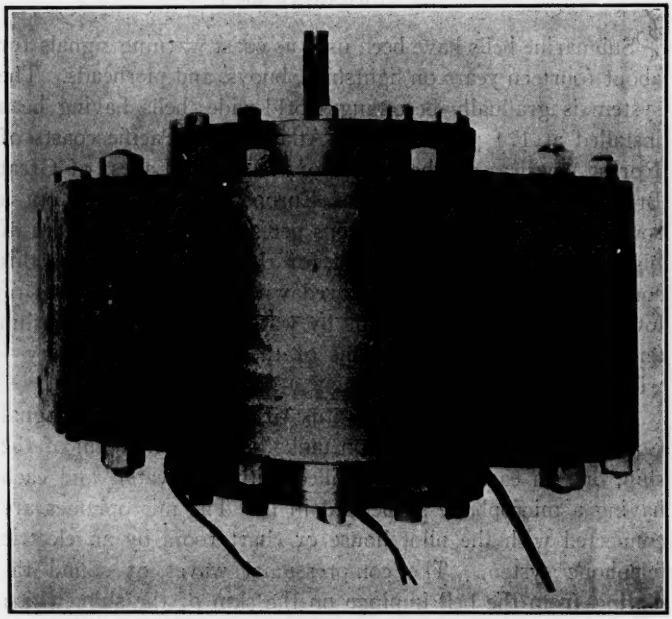


FIG. 1.—FESSENDEN SUBMARINE TELEGRAPH OSCILLATOR.

This problem has been solved, however, in a simple and effective way, both for producing and receiving sound signals, by Professor Reginald A. Fessenden, through his invention of the Oscillator, an electric mechanism which vibrates a diaphragm with sufficient force and frequency to generate compressional waves of sound in water. Conversely, the diaphragm, when acted upon by such waves and "listening," acts as a sound receiver. In his recent lecture before the American Academy of Arts and Sciences and the Lawrence Scientific Association in joint session, Professor Fessenden described the oscillator, as follows:

"The device used is termed an Oscillator, and its construction is shown in cross-section in the drawing, Fig. 2. In the drawing, the iron of the magnetic circuit and the copper tube are shaded. The magnetising coil is cross-hatched. The moving part is the copper tube *A*. This lies in the air-gap of a magnetic field, formed by a ring magnet *B*, built up in two parts, as shown in longitudinal section by Fig. 3.

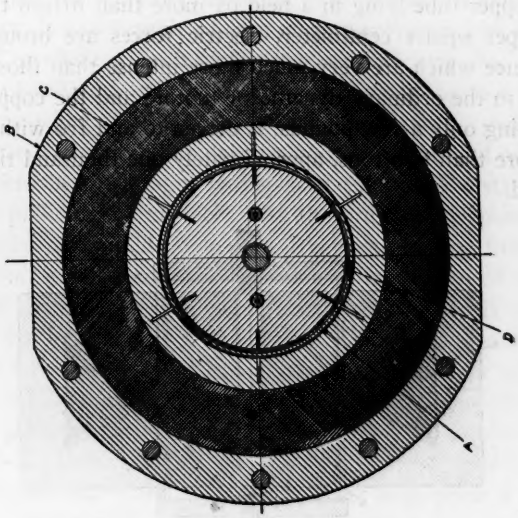


FIG. 2.—CROSS SECTION OF OSCILLATOR.

"The ring magnet is energized by the coil *C*, and produces an intense magnetic flux which flows from one pole of the ring magnet across the air-gap containing the upper part of the copper tube, thence through the central stationary armature *D*, thence across the other air-gap to the lower pole face of the ring magnet, and thence through the yoke of the ring magnet back to the upper pole face. This field is very much stronger than that in the ordinary dynamo, there being more than fifteen thousand lines for each square centimeter of cross-section.

"Around the armature is wound a fixed winding which we

will call the 'armature winding,' and which is reversed in direction so that one-half of the winding is clockwise and the other counter clockwise. When an alternating current is passed through this 'armature winding' it induces another alternating current in the copper tube, the actual value of which is approximately ten thousand ampères. This current of ten thousand ampères flowing through the copper tube, and the copper tube lying in a field of more than fifteen thousand lines per square centimeter, electric forces are brought into existence which are very much more intense than those which occur in the ordinary dynamo or motor; and the copper tube, weighing only a few pounds, is driven to and fro with a force of more than two tons, approximately one thousand times per second.

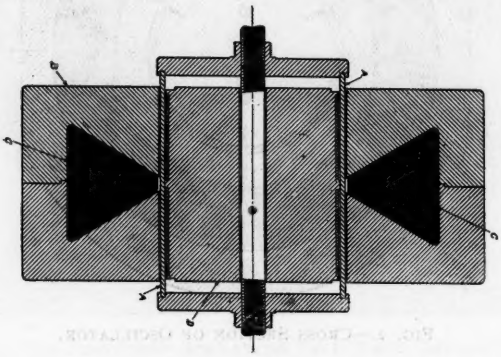


FIG. 3.—LONGITUDINAL SECTION OF OSCILLATOR.

"Only by this construction has it been found possible to obtain the enormous force and rapidity necessary to compress the water and to overcome the inertia of the moving parts of the mechanism. In order to apply this force to the work of compression, the copper tube is attached to solid discs of steel, which in turn are attached to a steel diaphragm one inch thick, or to the side of the ship. In practice the tube is provided with lugs, and is held between two discs drawn together on the tube by a one-inch vanadium-steel rod and a right- and left-handed screw thread.

* * * "So much for the apparatus when in use as a sound generator. The signals produced by the oscillator can, of course, be received by water-immersed microphones of the usual type, but one would perhaps not expect the possibility of using the oscillator as a receiver, in view of the fact that the diaphragm is of solid steel and weighs, with the copper tube and its attachments, considerably over one hundred pounds; but the oscillator, as in the case of the ordinary electric motor, is also capable of acting as a generator, and, on account of its efficiency as a motor, is a very efficient one.

"This oscillator—which we have just been using as a sound producer—when used as a generator of electricity, generates one-thirtieth of a volt, at a frequency of one thousand per second, when the diaphragm is displaced through a distance of one one-millionth of an inch. As the ordinary telephone receiver gives an audible note at a frequency of one thousand per second, with approximately one three-hundredth of a volt, it will be seen that an audible note will be produced if the oscillator diaphragm be set in vibration through a distance of only one ten-thousandth of one-millionth of an inch or approximately one ten-billionth of an inch. * * * The same oscillator is therefore used for sending and for receiving, a switch being thrown in one direction when it is desired to telegraph under water, and thrown the other way when it is desired to 'listen in.'"

The oscillator, constructed as described above, has unique advantages in the absence of self-induction, hysteresis, and eddy currents. There are two reasons for this: the tube forms the short-circuiting secondary of a transformer whose primary is the armature winding; and, second, the upper and lower portions of the winding are wound in opposite directions, which eliminates mutual induction. Magnetic leakage in the armature circuit is reduced to a minimum and eddy currents are prevented wholly. At a frequency of 500 per second, the oscillator delivers 35 kw. in mechanical power to the water with an efficiency of over 90 per cent.; at a piston speed of 1,000 feet per second, the output is about 1,000 kw. The

oscillator may be attached directly to the plating of the ship or mounted on the inner skin, the space between the diaphragm and the plating being filled with water or other compressible fluid.

APPLICATIONS OF THE OSCILLATOR.

By depressing a key and throwing a switch, current enters the oscillator, causes the tube to vibrate, and produces compressive sound waves of any desired frequency in the water outside the ship, and those waves can be received and their signals read by a similar oscillator in another vessel. As in ordinary telegraphy, the key can be so operated as to transmit signals by the Morse or cipher codes. During recent tests at the Boston lightship, it was found that, with but 10 per cent. of the full power of the oscillator telegraphic signals could be read at a distance of 30 miles, and with the receiver a foot away from the ear. The curve of intensities plotted from these tests shows that the signals would still have been intelligible at 112 miles, even at this reduced power. Again, in some preliminary tests of under-water telephoning, the apparatus—using only six dry cells and an ordinary telephone transmitter—operated successfully through a distance of more than half a mile. With suitable power and another oscillator as receiver, Professor Fessenden believes that a distance of at least five miles could readily be reached.

While extended experiments have not yet been made, there seems to be no question that the oscillator will show by submarine echoes the presence of icebergs, since seven-eighths of the bulk of a berg is below the surface, and it has been found that ice will reflect submarine sound waves.

Captain J. H. Quinan, U. S. R. C. *Miami,* reports in the Hydrographic Office Bulletin of May 13, 1914:

"We stopped near the largest berg, and by range finder and sextant computed it to be 450 feet long and 130 feet high. Although we had gotten within 150 yards of the perpendicular face of this berg and obtained no echo from the steam whistle, Professor Fessenden and Mr. Blake, representatives of the Submarine Signal Company, obtained satisfactory results

with the submarine electric oscillator placed 10 feet below the surface, getting distinct echoes from the berg at various distances, from one-half mile to two and one-half miles. These echoes were not only heard through the receivers of the oscillator in the wireless room, but were plainly heard by the officers in the wardroom and engine-room storeroom below the water line. Sound is said to travel at the rate of 4,400 feet per second in water. The distance of the ship, as shown by the echoes with stop watch, corresponded with the distance of the ship as determined by range finder."

A novel function, possible to the oscillator by the principles of reflected sound, is the making of continuous soundings. With regard to this echo-sounding, Professor Fessenden says:

"If we take a commutator wheel with one live segment and two brushes, one connected to the A.C. generator and the other to the telephone receiver, it will be evident that, when the commutator segment makes contact with the brush connected to the generator a sound will be produced by the oscillator. When the live contact passes away from the brush the sound will cease, having lasted—if the peripheral speed of the commutator is one mile per minute and the width of the brush one-quarter of an inch—for approximately one two-thousandth of a second. This sound wave will travel outward, and, on reaching the bottom, will be reflected and travel back again to the ship. Meantime, no sound will be heard in the telephone receiver; but, if the brush connected to the telephone receiver be shifted in the direction of rotation of the commutator until it makes contact with the live segment of the commutator, at precisely the instant at which the reflected sound wave has come back and impinged on the oscillator diaphragm, then a sound will be heard. Since sound travels in water at a velocity of approximately 4,000 feet per second, if the distance be 100 feet, the time taken by the sound, in traveling from ship to bottom and from bottom to ship, will be approximately one-twentieth of a second, and the distance between the position of the two brushes will be approximately 50 inches.

"As the position of the brushes can be located easily to within one-quarter of an inch, it will be evident that continuous soundings can be taken in this way to an accuracy of approximately six inches. In practice the commutator speed is only about one-half of a mile per minute, and the circle on which the receiver brush travels is graduated directly in feet. The success of this method is due principally to the fact that in the oscillator we possess a source of sound of great intensity and one capable of acting almost instantaneously, the time-constant of the oscillator being less than one ten-thousandth of a second. Consequently, though the amount of sound reflected is comparatively small, it is nevertheless sufficient, since a source having unit audibility at 100 miles will have an audibility of five million at a distance of 100 feet, so that, if only one part in five million be reflected back from the bottom, the reflected wave would still be audible."

Captain Quinan, in the report cited previously, says: "Anchored in 31 fathoms of water with 75 fathoms of chain, in order to make current observations. * * * Professor Fessenden took advantage of the smooth sea to further experiment with his oscillator in determining by echo the depth of water, the result giving 36 fathoms—which seemed to be very close."

The oscillator can also be used for transmitting sound through solids—an application which, if suitably developed, might be of value for intra-communication on shipboard in action. For example, if a steel rod of any length be attached to the oscillator at one end and to a diaphragm at the other, the oscillator will produce compressive waves in it and the diaphragm at the other end will give out sound. Other obvious applications of the oscillator are the determination of the distance between ships and the steering of dirigible torpedoes.

THE SOUND SHADOW.

Every ship casts a "sound shadow" on the side away from the source of sound. The simplest way to explain its formation is to use the analogy of light. Imagine a searchlight

thrown from a distance against a ship: on the side of the ship away from the light, there will be a shadow. In a similar manner, the sound radiating from a submarine bell or oscillator at a distance, is shut off from the side of the ship away from the source of sound. When listening on the microphone or oscillator on the side of the ship nearest the source the signal can be heard plainly. When listening similarly on the other side of the ship no signal will be heard.

The difference between light and sound is due apparently to the lengths of the respective waves. A light wave is extremely short, whereas a sound wave of a pitch of a thousand vibrations per second is, in water, about four feet long, and one of five hundred vibrations is eight feet long. In consequence of this a light shadow has a very sharp line, as the wave is not long enough to bend around a corner. A sound shadow is blurred at the edge owing to the fact that the wave is long enough to bend around the corner for approximately half a wave-length.

It makes no difference which way an unscreened microphone—two inches in diameter—faces. It will hear the sound equally well when facing in any direction. Placing a screen in front of the microphone makes no difference, until the screen is sufficiently large to make the distance from its edge to the microphone approximately half a wave-length. For effective use of the sound shadow, care must be taken, therefore, to have a screen which is large enough to cast a positive shadow, and to place the microphone or oscillator in the heavy shadow away from the fringe at the edge of the screen. In practice, of course, the body of any vessel, excepting very small boats, is sufficiently large to provide an ample screen.

DIRECTION FINDING.

Fig. 4 illustrates the service of the sound shadow in finding the bearings of a submarine bell or oscillator by the receiving apparatus in a ship's bows. Let the ship be headed north and the bell be east northeast from it, as in Diagram No. 1. The starboard microphone transmits a sound; the port micro-

phone is silent (unless the bell is less than a mile away, when there will be a faint sound on that side). Evidently, the bell is to starboard. No. 2 shows the course changed to northeast. Both microphones now transmit sound, but the starboard is the louder, and hence the bell must still be on that

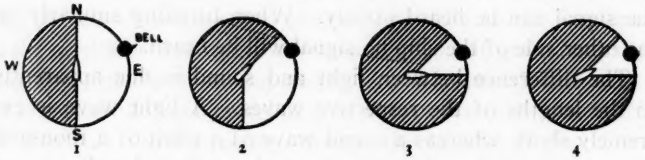


FIG. 4.—SUBMARINE SIGNAL DIRECTION FINDING.

side. In No. 3, the ship is heading east, and, while both microphones sound, the port is now the louder. No. 4 shows the ship swung back two points to port with the bell dead ahead, its sound being now the same in strength on both sides.

THE WALL OF SOUND.

The range of the oscillator is so great that it would be readily possible to guard a dangerous or much traveled section of coast line by signal stations from 25 to 50 miles apart whose fields would touch, so that, as shown in Fig. 5, the

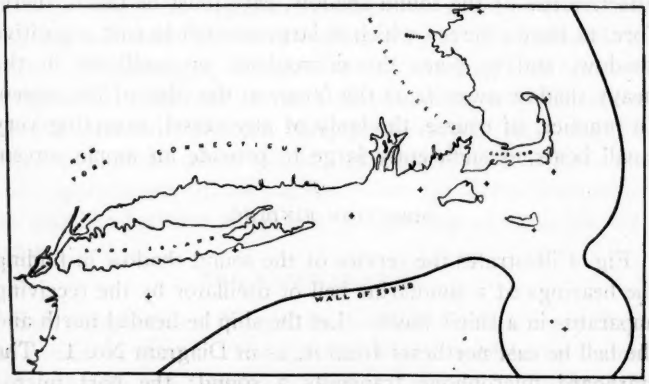


FIG. 5.—THE WALL OF SOUND.

shore would be encircled by a "wall of sound" within which no vessel, equipped with receiving apparatus, could enter in fog, storm or darkness without full warning of her exact position, no matter how far variable currents or dead reckoning may have led her astray.

Professor Fessenden's apparatus, while doubtless not the last word in submarine signalling in this inventive age, has unquestionably a wide and most varied field. In the simplicity of its design and the compact way in which the mechanism for generating a relatively enormous and instantaneously acting force is compressed into small space, the oscillator is a noteworthy example of the precision and elegance which characterize so many American achievements in science. In war and peace it will make inter-ship communication readily possible in all conditions of weather and sea, and it has solved an age-long problem in meeting effectively the dangers of the fog—that pall which has hung over the seas of the world since first the hardy Phoenician mariners fared forth through the Pillars of Hercules into the Western Ocean to seek the far Cassiterides.

NOTES.

THE PROTECTION OF BATTLESHIPS AGAINST SUBMARINE ATTACK.*

By Professor Sir John H. Biles, LL.D., D.Sc., Vice President.

In a lecture delivered in March last at the Royal Institution, I ventured to remark in relation to the War Navy that the "use of oil and turbines has so reduced the weight of motive power that much higher speeds can be got for the weight that was appropriated in the coal-burning earlier ships. It may be that some of this advantage may be made use of to reduce the size of ships and increase their number. It may be that armor may to some extent be sacrificed, and gun attack be allowed to be more effective in order that some compensation should be available for the effect of torpedo attack. It will thus be seen that the increasing destructive effect of the torpedo brings into the battleship problem the possibility of changes which may once again revolutionize warship design."

The "Times" opened its columns in May to a full discussion of the impending obsolescence of battleships and the coming of the submarine as the dominant fighting ship. In the discussion, it was generally assumed that if the submarine could get within striking distance the battleship must be destroyed. If my memory does not deceive me, it seems that the advent of the spar-torpedo and that of the almost-invisible small torpedo boat was heralded in the same terms. Some of us have lived to learn the limitations of these cheap methods of destruction, and before too rapidly breaking up our battleships and building no more of them, it may be well to consider what, if any, defence can be given to these poor, helpless ships.

In this Institution we have a meeting ground for the statesman, the naval officer and the ship constructor. The first directs the second, and the third supplies the second with his weapon. We ship constructors are sometimes taken into the confidence of the naval officer, and we try to understand as much as we can of the nature of the onerous duties which he has to perform. We are told that the Navy exists to keep the command of the sea, and that command of the sea is necessary for its freedom. To keep the command it is desirable—some say, necessary—to discover and destroy the enemy's forces. Battleships, cruisers, destroyers, submarines, must all be caught and destroyed or captured, and, equally, all must be capable of resisting destruction or capture. In the two dimensions represented by the surface of the sea, with equal powers of vision, getting within destroying distance is a question of speed, and destruction is a matter of superiority of attack over the defence. The dominating weapon of attack has been the gun, and the defence against it has been practically all above water, because there its attack has been made. The torpedo boat and, later, the destroyer, have delivered their main attack below water, but the attacked ship is held to be quite capable of delivering a counter attack by guns above water, which is an adequate reply to the destroyer. The attack of the submarine is wholly below

*Paper read before the Institution of Naval Architects at Newcastle, on July 7, 1914.

water, and so far the attacked ship has developed no effective reply of its own. The defence against the gun is armor and other guns. The defence against the destroyer's torpedo is the gun, which is quite ineffective against the submarine. The question of interest at the moment is, What defence can the surface ship have against the submarine's torpedo?

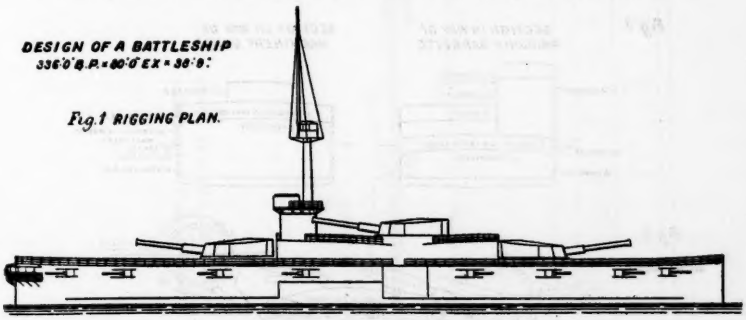
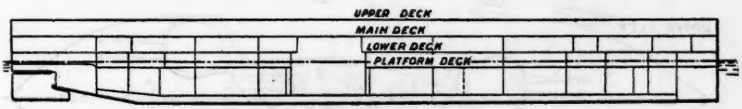
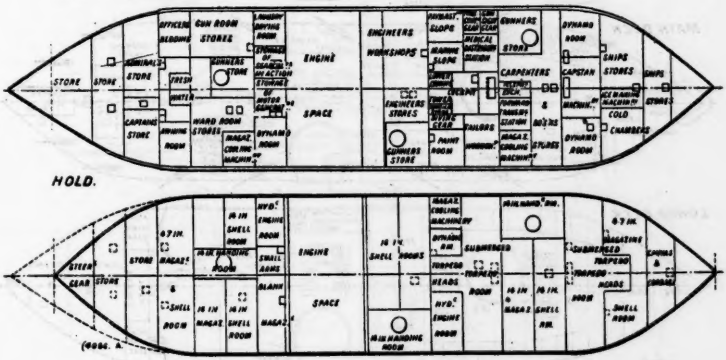


Fig. 1 RIGGING PLAN.



PROFILE SHEWING SUBDIVISION.

Fig. 2. PLATFORM DECK.



There can be only two forms of defence. First, the destruction of the submarine by other vessels, submarines, or others. Second, the protection of the bottom of the surface ships from the effects of under-water attack. The first, the destruction of the submarine, is obviously not the work of a battleship or large cruiser, but must be left to some vessel of the same

order of size as the submarine. This destruction must be sought on the surface when the submarine is not submerged, for it seems improbable that a submarine will be able to chase another effectively under the water. In any case, the submarine will be dangerous to the large surface ship until it is destroyed, and, as the means of destruction are not yet certainly to hand, the question of effectively protecting the battleship against

Fig. 3.

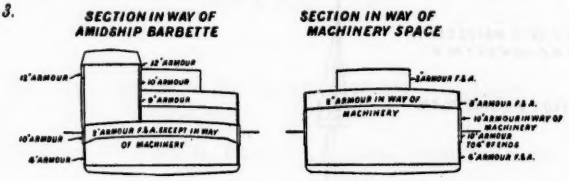
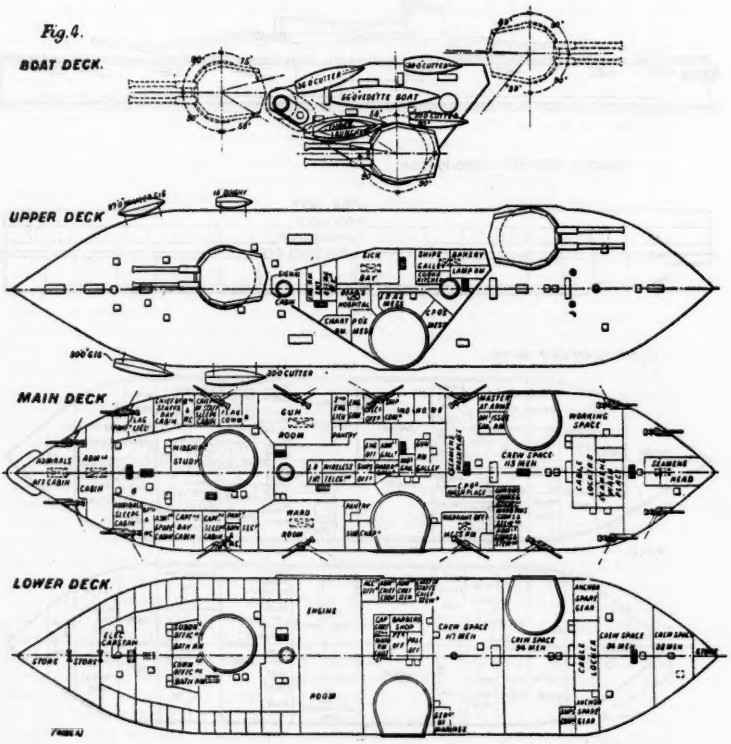

SECTION IN WAY OF AMIDSHIP BARBETTE
SECTION IN WAY OF MACHINERY SPACE
12" ARMOUR
10" ARMOUR
9" ARMOUR
5" ARMOUR F.&A. EXCEPT IN WAY OF MACHINERY
6" ARMOUR
5" ARMOUR F.&A.
8" ARMOUR IN WAY OF MACHINERY
6" ARMOUR F.&A.
10" ARMOUR IN WAY OF MACHINERY
10" ARMOUR TOE OF ENDS

Fig. 4.

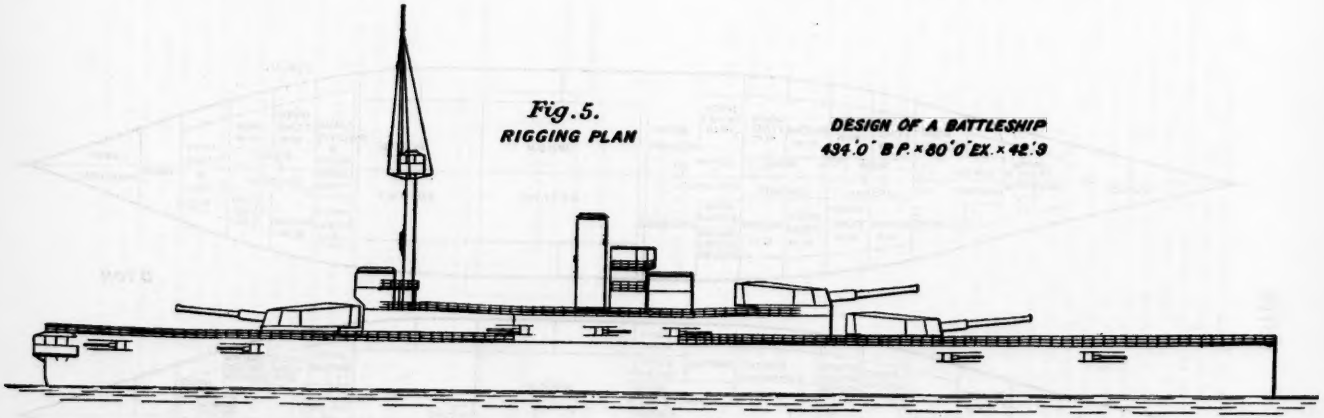


under-water attack seems to be deserving of consideration, unless some one is ready with a real reply to the submarine.

One naturally is first met with the question: What about the weight of such protection The same question can, of course, be asked in the same

Fig. 5.
RIGGING PLAN

DESIGN OF A BATTLESHIP
434'.0" B.P. × 80'.0" EX. × 42'.9



PROFILE SHOWING SUBDIVISION

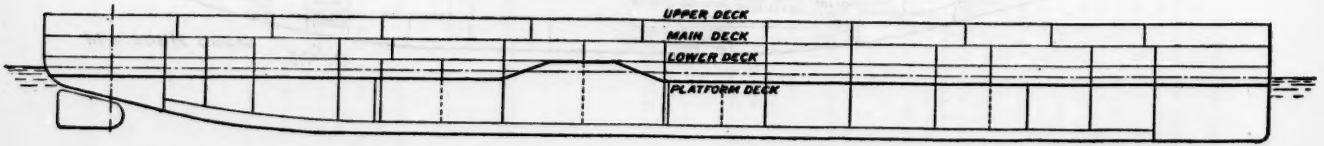
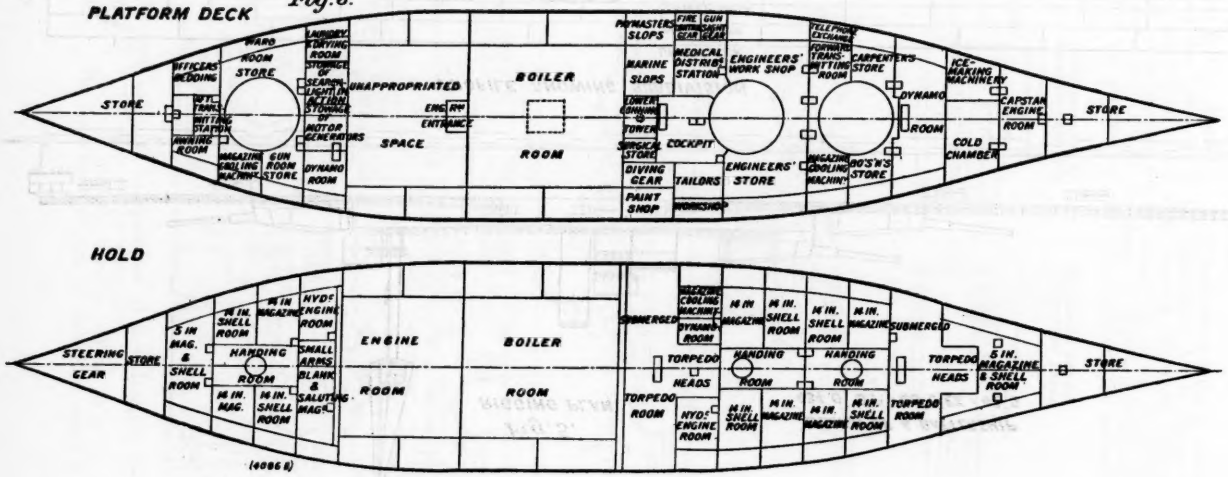


Fig. 6.


PLATFORM DECK
STORE
OFFICERS MESSING
W.T. TRANSMITTING STATION
AWNING ROOM
WARD ROOM STORE
MAGAZINE COOLING MACHINE
GUN ROOM STORE
LAUNDRY DRYING ROOM
STORAGE OF SEARCH LIGHT IN ACTION
STORAGE OF MOTOR GENERATORS
DYNAMO ROOM
UNAPPROPRIATED SPACE
ENG. R.M. ENTRANCE
BOILER ROOM
PAYMASTERS SLOPS
MARINE SLOPS
LOWER CONNING TOWER
SURGICAL STORE
DIVING GEAR
PAINT SHOP
FIRE EXTINGUISHING GEAR
GUN LAYING GEAR
MEDICAL DISTRIBUTING STATION
COCKPIT
TAILORS
WORKSHOP
ENGINEERS' WORK SHOP
ENGINEERS' STORE
TELEPHONE EXCHANGE
FORWARD TRANSMITTING ROOM
MAGAZINE COOLING MACHINE
CARPENTER'S STORE
DYNAMO ROOM
OO'S W'S STORE
ICE-MAKING MACHINERY
CAPSTAN ENGINE ROOM
COLD CHAMBER
STORE
HOLD
STEERING GEAR
STORE
3 IN MAG. & SHELL ROOM
4 IN. SHELL ROOM
4 IN MAGAZINE
HYD.L ENGINE ROOM
HANDING ROOM
SMALL ARMS, BLANK & SALUTING MAG.
4 IN. MAG.
4 IN. SHELL ROOM
ENGINE ROOM
BOILER ROOM
TORPEDO ROOM
SUBMERGED
MAGAZINE COOLING MACHINE
DYNAMO ROOM
TORPEDO HEADS
HYD.L ENGINE ROOM
6 IN MAGAZINE
4 IN. SHELL ROOM
HANDING ROOM
SUBMERGED TORPEDO HEADS
6 IN. MAGAZINE & SHELL ROOM
STORE

(4086 K)

attitude of mind about any weights used in a ship for the purpose of attack or defence. What about the weight of armor to keep out shot? The thickness and extent of protection ought to be proportioned to the liability to be hit and the damage done when hit. The principle is given effect to when distributing armor protection over a ship to resist gun fire. What is the relative damage done by a 15-inch shell and a 21-inch torpedo, and what is the relative liability to be hit by these projectiles? A distinguished gunner told you in this Institution in April that a modern battleship will be destroyed by gun fire in five minutes after fighting range has been reached. The submarine officer will tell you he can get a torpedo into any ship that he can see and can get within the range of his torpedo. The battleship can hit back at his enemy battleship, but can do nothing by himself against the submarine. What is the liability to be hit in the two cases? Can the submarine find the battleship as surely as the enemy battleship can? In other words, what is the relative liability to be hit by the two methods of attack? This is for the naval officer to tell us, if he can. If the relative liability to be hit is sufficiently great to warrant full consideration of the relative damage, we shall also want to know this. Assuming, as one reasonably may, that very serious damage will be done by the explosion of a torpedo, the next question is, What can be done to prevent or seriously to reduce this damage? Subdivision naturally suggests itself as one means of minimizing the effect of this damage, but when all that is possible in this direction has been done, there seems to be no great certainty that a battleship will be still a formidable fighting machine after having received the successful contact explosion of a 21-inch torpedo. Can we do anything in addition to subdivision to preserve the ship for effective fighting purposes?

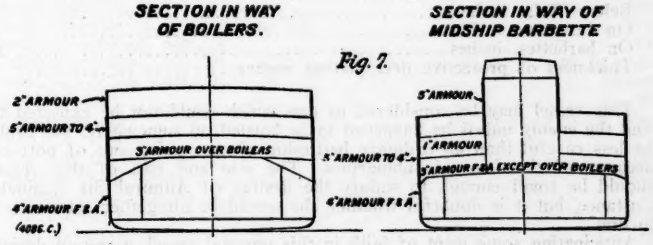


Fig. 7.

Armor on the bottom of warships has been proposed by responsible persons. Sir E. J. Reed and General Sir John Crease, R. M. A., during their lives made definite proposals of this character, but they have never been adopted on the outsides of ships, partly for the reason that, previous to the submarine, the torpedo-carrying vessel has been effectively answered by the gun, and partly because the resisting qualities of armor, when submitted to attack by torpedoes, have not been sufficiently well known. The effective advent of the submarine seems to justify a serious consideration of the question of applying armor to the bottoms of ships.

The question of the weight of such armor must be serious, and obviously the addition of such weight cannot be made without some changes and sacrifices. To some it may seem that the readiest way to approach this problem is to clothe the bottom of a 25,000-ton battleship of the latest pattern with armor, and to increase her fullness sufficiently to allow her to carry this armor, letting everything else remain unaltered. The only considerable effect will be to reduce the speed by 2 knots.

This is a direct and simple issue—is the gain in protection worth the loss

of speed? That is for the naval officer to decide. The constructor will naturally find difficulties in the way of attaching such armor protection, but he has surmounted difficulties before, and if the naval officer thinks the result worth attaining, the difficulties will doubtless be overcome.

It is not always that the readiest way of approaching a problem gives the best result. One of the characteristics of our latest battleships is that their forms have a low resistance to forward motion. If a form is produced which is better adapted to fitting and carrying armor, though it may involve greater resistance or less speed, it may on the whole be better to adopt such a form. It may be interesting to give an instance or two of the application of this principle. Admiral Sir Reginald Custance has taken us into his confidence about some of his views on the principles which he thinks should underlie naval design. His appreciation of lower speeds and smaller displacements led me to work out what appeared to me to be a limiting case of his views, but combined with these characteristics was associated in this case an armored protection from torpedo attack. The principal elements of the resulting design were as follows:

Length over all, feet	358
Length between perpendiculars, feet	336
Breadth, extreme, feet	80
Draught of water, feet	20
Displacement in tons	13,000
Speed, knots	10
Armament	six 14-in., sixteen 5-in.
Thickness of armor:	
On side at W.L., inches	10
Above W.L., inches	3
Below W.L., inches	4
On casemate, inches	2
On barbettes, inches	12
Thickness of protective deck-plating, inches	2

This vessel may be considered as one which could not be expected to find the enemy unless he happened to be bottled up somewhere, but could be less careful than an ordinary battleship about coming out of port on account of the fear of submarines. The size and cost of this vessel should be small enough to satisfy the desires of Admiral Sir Reginald Custance, but it is doubtful whether she would be altogether satisfactory to him.

Anticipating some want of faith in this unusual vessel, a second design was produced having some of the characteristics of the first, but being produced with less disregard of convention. The principal elements are as follows:

Length over all, feet	460
Length between perpendiculars, feet	434
Breadth, extreme, feet	80
Draught of water, feet	24
Displacement, in tons	16,000
Speed, knots	18
Armament	six 14-in.; sixteen 5-in.
Thickness of armor:	
On side at W.L., inches	5
Above W.L., inches	5
Below W.L., inches	4
On casemate, inches	2
On barbettes, inches	5
Thickness of protective deck-plating, inches	2

This vessel is of about the displacement of the *Lord Nelson*, which is, when purpose serves, called a Dreadnought. The armament is about the same as the first design, but the armor has been reduced so that it will only keep out 6-inch projectiles. Sir Reginald's view is that none of our ships have armor that will do more, and, that being so, this ship may be considered as sufficiently well armored above the water line. All the sections below the water line are straight, with a circular arc at the end. This form has been adopted to simplify the armor construction of the bottom. It is fully recognized that such a design outrages the convictions of the economists, to whose ranks I want to belong, because ships of such size do not produce the greatest number of guns for a given expenditure. But if we are to be subjected to the ready loss of ships by submarines we may have to be prepared to sacrifice some gun power for our expenditure, and get our recompense in the greater number of ships and guns remaining afloat after the submarine has done its work. It is very rash on the part of a mere naval architect to attempt to reach any conclusion on this difficult question. The facts and figures are placed before this Institution, so that those who are competent to form an opinion may have the opportunity of doing so.

With a view to enabling those who do not believe in reducing the upper armor of a ship, nor in such a low speed as 18 knots, another design has been considered in which the bottom is armored, and is of a form similar to the second design, but in which the speed, armor, and armament are of the same order as the Dreadnoughts. Such a vessel could take her place in the First or Second Battle Squadron, and would have armored protection against torpedoes. The principal elements are as follows:

Length over all, feet	600
Length between perpendiculars, feet	570
Breadth, extreme, feet	91
Draught of water	28 ft. 6 in.
Displacement, in tons	28,500
Speed, knots	21
Armament	ten 14-in., sixteen 6-in.
Thickness of armor:	
On side at W.L., inches	10
Above W.L., inches	7 and 5
Below W.L., inches	4
On casemate, inches	2
On barbettes, inches	12
Thickness of protective deck-plating, inches	3

Briefly, the points for discussion are as follows:

1. Is 4-inch armor sufficient protection against torpedoes to justify its adoption in battleships of the class of the later Dreadnoughts?

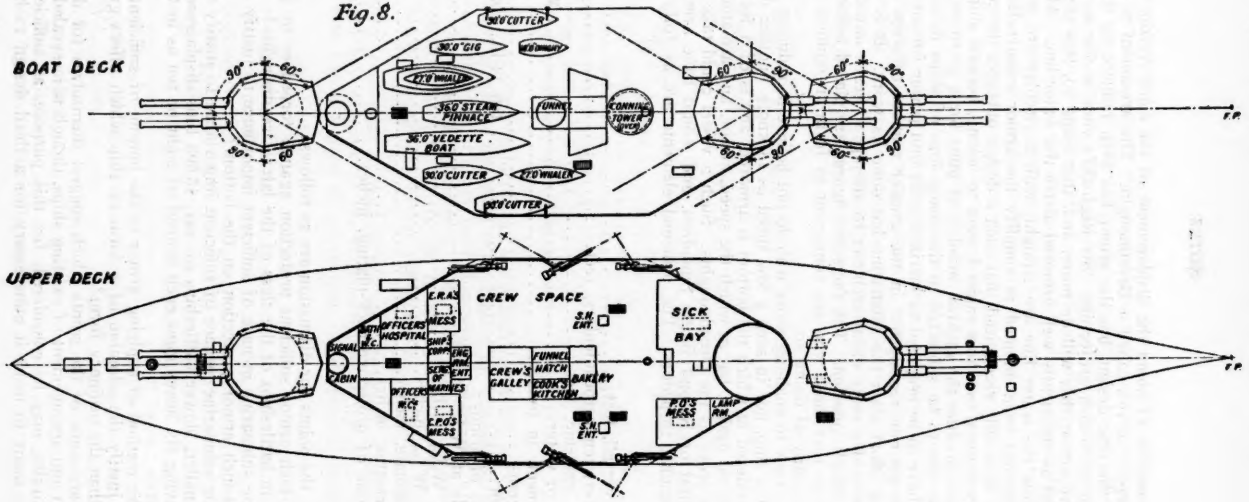
2. Is the submarine menace of sufficient importance to justify the adoption of 4-inch armor protection on the bottom?

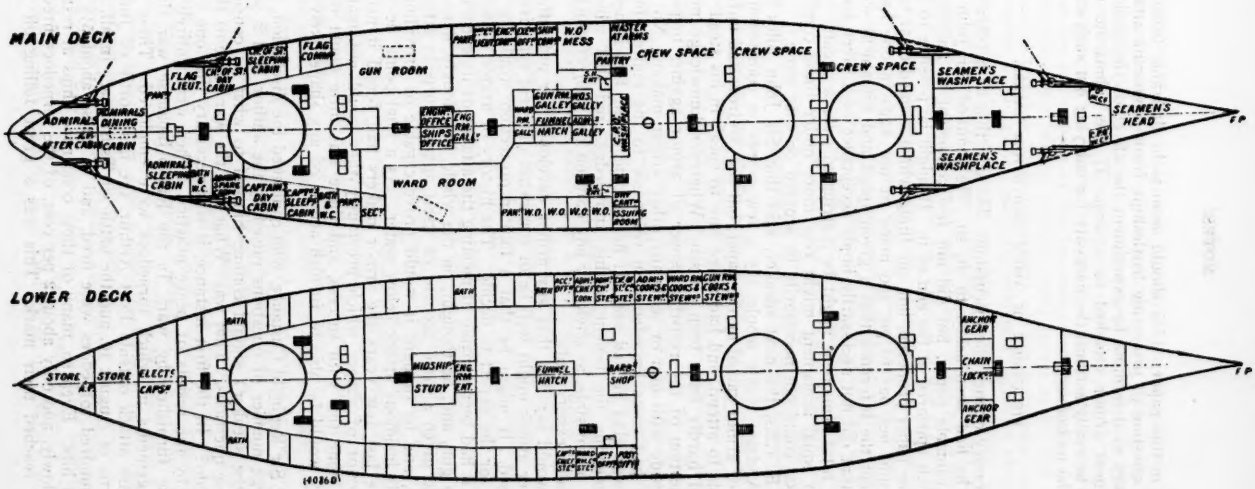
3. Is the submarine menace of sufficient importance to justify the building of smaller, slower battleships of, say, 16,000 tons displacement, of 18 knots, having six heavy guns each instead of eight or ten as in the larger ships?

4. Is the method of applying armor to the bottom of sufficient value in itself to justify the adoption of a form of ship which offers greater resistance than the ordinary form?

These are some of the points which suggest themselves for discussion. The form and arrangement of existing ships, though not revealed to us by the Admiralty, may be considered, for this purpose, as sufficiently well known to many to make it unnecessary for a third design to have been

Fig. 8.


BOAT DECK
36'0" CUTTER
36'0" GIG
36'0" DINGHY
27'0" WHALER
36'0" STEAM PINNACE
FUNNEL
CONNING TOWER (HCS)
36'0" VEDETTE BOAT
36'0" CUTTER
27'0" WHALER
36'0" CUTTER
30°
60°
90°
F.P.
UPPER DECK
CREW SPACE
E.R.A.'S MESS
OFFICERS HOSPITAL
SICK BAY
S.H. ENT.
SIGNAL
CABIN
OFFICERS W.C.
SHIP'S OFFICE
ENG. ROOM ENT.
SERGTS OF MARINES
FUNNEL HATCH
CREW'S GALLEY
COOK'S KITCHEN
BAKERY
P.O.'S MESS
LAMP RM.
C.P.O.'S MESS
S.H. ENT.


MAIN DECK
ADMIRALS
ADMIRALS DINING
AFTER CABIN
CABIN
FLAG LIEUT.
CHF OF STF DAY CABIN
CHF OF STF SLEEPING CABIN
FLAG COMMR
GUN ROOM
ENGINEER OFFICER
SHIPS OFFICE
ENG. RM. GALL.
W.O.' MESS
MASTER AT ARMS
PANTRY
CREW SPACE
CREW SPACE
CREW SPACE
SEAMEN'S WASHPLACE
SEAMEN'S WASHPLACE
SEAMEN'S HEAD
FP
ADMIRALS SLEEPING CABIN
BATH & W.C.
CAPTAIN DAY CABIN
CAPTAIN'S SLEEPING CABIN
BATH & W.C.
SECY
WARD ROOM
GUN RM GALLEY
W.O.S GALLEY
FUNNEL HATCH
GUN RM GALLEY
W.O.S GALLEY
W.O.
W.O.
W.O.
W.O.
CAPTAIN'S PANTRY
SHIPS CLOTHES ISSUING ROOM
LOWER DECK
STORE
STORE
ELECTN CAPS
BATH
BATH
BATH
MIDSHIPS STUDY
ENG. RM. ENT.
FUNNEL HATCH
BARBR'S SHOP
ANCHOR GEAR
CHAIN LOCKER
ANCHOR GEAR
FP
(4086D)

embodied in this paper. If it should seem to be desirable further to consider this question of protecting battleships from submarine attack, it will be necessary to determine by experiment the effect of the explosion of a torpedo upon armor attached to a ship. If the submarine menace is judged to be really serious, the necessity for carrying out such experiments seems to be undoubted.

DISCUSSION OF ABOVE AND OTHER PAPERS.

Lord Brassey opened the discussion. He said that as a veteran and old president he had been asked to do so. He thanked Sir John Biles for his most valuable paper, but did not feel competent to answer the four points which appeared at the end of it. It might be possible to build such ships as the paper proposed, but one thing which seemed clear to him was that it would not pay to put too many of our eggs in one basket. We might accept the inference that a given speed and armament were necessary, but that did not necessarily imply acceptance of a given size of ship. The same total armament might be distributed over a greater number of ships. An equal armament might cost more under these conditions, but the proposal could not necessarily be scouted on that score.

Mr. C. E. Ellis, the next speaker, said that Sir John Biles had hoped that Sir Andrew Noble would say a few words in connection with the questions of armor raised by the paper, but Sir Andrew had unfortunately been unable to attend, and had asked him to speak in his stead. A worse man could hardly have been chosen. Whatever knowledge might exist on the question of the resisting power of armor against torpedo attack did not reside with him or with any other armor maker. No doubt the Admiralty had some knowledge in reference to the matter, but he had not. He was glad he had not. If he had, he might feel it necessary to give the meeting the benefit of his knowledge, and that would hardly have been permissible, as obviously any data on the subject must be based on Admiralty experiments.

All he would say was that any armor developed for protection against under-water attack might well be of somewhat different type from that at present used. It might be that a lighter protection would be sufficient. That was for the expert to decide. The history of armor showed that on the whole it had been capable of meeting the attacks of its enemies. It had fought the gun, and, he thought, on the whole, had fought it successfully. It had also given a good account of itself against torpedo attack on the water line, and he thought it would prove capable of providing defence against this insidious attack below water. As a final point, he would say that in the last few years the armor makers had found it necessary to provide armor of shapes which previously they could not manufacture. They had done this with success, and there was little doubt that in the future they would be able to furnish armor of any shape likely to be required.

Admiral Sir Reginald Custance, who continued the discussion, said there were a large number of questions raised by the author, and it was necessary he (the speaker) should confine himself to what he considered the gist of these questions. That was: What was the war value of the Whitehead torpedo? In the first instance, it was necessary that one should not be misled by the results of peace practice. They were entirely different from those furnished by war. In the Russo-Japanese war there were four engagements in which torpedoes were employed. These were the first surprise attack outside Port Arthur, the first sortie of June 23, the second sortie of August 10, and the battle of Tsushima. In all, some two to three hundred torpedoes were fired, and of these about 5½ per cent. resulted in hits. Even so, many of these concerned ships at rest or moving very slowly, and only about 2 per cent. of the torpedoes fired at ships in motion reached their mark. This was a great falling off from the

results of peace practice. It should further be noted that no ship sank immediately on being struck by one torpedo. The ships that foundered at once had been hit by three or four torpedoes, and had further been much damaged by gun fire. These figures suggested that there was a very fair probability against a particular torpedo doing much damage.

What was the explanation of the low percentage of hits? At the time of the Russo-Japanese War a torpedo could travel at 50 feet a second. Now they could travel at 75 feet a second. When a torpedo was fired at a ship in motion it had to be aimed a considerable distance ahead of her; and as her speed and course were not known, great difficulty was introduced. Further uncertainty arose from the fact that one was not certain about the speed of his own torpedo; also it was necessary to fire it at the exact moment when the sights were on. This was not easy. Then questions of imperfect management crept in. The torpedo was set for short range, and fired for long range, and so on. Again, torpedoes might be erratic, and sometimes turned round and came back at the boat that had fired them. Not very often, perhaps, but still it might be in 1 per cent. of cases. When all these difficulties came in, and had to be allowed for on a dark night under gun fire, when the enemy was suddenly sighted, the wonder was that torpedoes ever hit their mark at all. Besides, all this went on at very close range—within 400 yards—when gun fire became a very serious matter.

Errors in the course and speed of torpedoes also depended on the speed ratio. This was the ratio between the speed of the torpedo and the speed of the ship. From the point of view of this ratio, nothing must be taken off the speed of the ship. In the Russo-Japanese War the cruisers had a speed of about 17 knots, and the battleships a speed of from 13 to 8 knots, or even less. The speed ratios varied from 5/3 to 4/1. The ratio had not changed at the present day, as the increased speed of the torpedo had been offset by the increased speed of the ships. Errors of torpedo course also depended on the direction of attack—whether it was on the beam or right ahead, and it was difficult on a dark night to know if one was on the beam or not. Changes of hits were further dependent on the length of the ship and the angle she subtended. From this point of view, long ships were a disadvantage. The broad results of the experience of the Russo-Japanese War was that the gun-armed surface vessel had successfully neutralized the torpedo-armed surface vessel. That could broadly be said of the effect of the destroyer on the torpedo boat.

These being the known war facts of the torpedo-armed surface boat, the question arose, How did they apply to the submarine? There was no war experience of the submarine, but she carried the same weapon, and the same errors were possible. Some people might say that the submarine was safer for those on board than was the surface boat, and that their mental equilibrium would be less disturbed. But this was a peace idea. In peace maneuvers the man on the submarine knew that the man he was attacking would do him no harm. In war, he knew he would do his best to destroy him. This introduced an incalculable factor, and one must guard against drawing too definite ideas from peace practice. One must reserve judgment. The struggle was really one between weapons—between the gun and the torpedo—between a gun-armed surface vessel in motion and a torpedo-armed submarine, which must come to the surface at times and so expose herself to gun attack. He might suggest a simile. A fight between the gun-armed surface vessel and the torpedo-armed submarine was rather like a fight between a man in the open with a repeating rifle and a man under cover with a blunderbuss, who had occasionally to poke his head up to see what he was about.

Sir Philip Watts, the next speaker, pointed out that the author had stated there could be only two forms of defence against submarines—destruction of the submarines and protection of the bottom of the ship by armor. He had not appeared to think torpedo-net defence worth men-

tioning, but this defence could be made fairly effective, especially so when ships were stationary. A certain amount of protection could also be obtained by fitting deep inner-bottom spaces, backed with tough protective plating, so that the loss of buoyancy resulting from a hit could be reduced to a minimum. Sir John had shown what it would involve if we had to armor-plate the sides of our ships to protect them against torpedo attack. If we retained the same speed, armor and armament as in the Dreadnoughts built during the last ten years, as many thought we should, the displacement would go up from 3,000 to 4,000 tons. The additional cost would be chiefly the cost of the introduction of the armor, which would be about £200,000. These ships would still be somewhat smaller and, he believed, less costly than ships building at present by certain foreign Powers.

With regard to the points for discussion enumerated at the end of the paper, he would say:

1. He thought 4-inch armor would afford sufficient protection against torpedoes if associated with suitable inner-bottom spaces, but it could be increased in thickness if desired.

2. Up to the present time the submarine menace had not been considered of sufficient importance to justify the adoption of armor protection on the bottom. Although discussed from time to time, it had never yet been seriously fitted.

3. He could not think that the power of gun attack was now relatively less than that of torpedo attack, but the reverse, and the importance of bringing the greatest number of big guns into the line of battle at least cost remained the same, and the value of speed remained the same. Hence the argument in favor of the big fast ship appeared the same.

4. It was probable that the admissible best form adapted for fitting and carrying armor would offer greater resistance than ordinary forms; but he was disposed to think there would not be very much in this. Resistance was very much more influenced by the longitudinal distribution of the displacement than by its transverse distribution.

Professor Hovgaard, who was the last speaker in the discussion, said that the problem discussed by Sir John Biles in his interesting paper was one of extreme importance, for on its solution depends the future of the large sea-going battleship. The question of the obsolescence of the battleship is really one of gradual restriction in its field of usefulness. Many people think that the battleship will be suddenly and absolutely abolished, and this idea has been advanced on several previous occasions when new weapons have appeared, but he believed that if the battleship was ever abolished it would only be as the result of a gradual process, perhaps of long duration. The Russo-Japanese War showed that the battleship could not safely approach fortified harbors, because the dangers of attack by floating mines were at all times very serious. In fact, the greater part of the losses by submarine attack during the war took place near the fortified places. At some distance from the coasts the battleships were fairly safe, being well prepared to meet the attack of surface torpedo craft. With the advent of the submarine boat the field of operation of the battleship at once became more restricted, although it cannot yet be said to what extent, since there is no war experience to go upon. It seemed certain, however, that large battleships would not now venture into narrow seas or near the coasts of an enemy unless they were absolutely forced to do so. For instance, he did not believe that they would venture into the Baltic if this sea was infested by the submarines of a powerful enemy, but, if they did, they must certainly operate with the greatest caution. The same remark applied to the Mediterranean, although with less force.

As yet the submarine did not threaten the battleship seriously on the ocean, and as long as this condition existed battleships must be built to control the ocean—that is, they must be of the largest class and armed with powerful artillery. When the ocean-going submarine is an accomplished fact our conclusion might be different, but we do not know when

this will happen, and perhaps by that time we shall be better able to meet submarine attack. It would be premature now to anticipate a danger that does not exist, and commence to construct small, poorly-protected and weakly-armed vessels. Battleships should be constructed to meet existing conditions, and not conditions that may not be realized for a number of years. The question is, then, How best to protect the large battleships against submarine attack?

There are two positive ways in which this may be accomplished. One is by means of armor, the other is by means of the so-called "elastic" bulkheads—*i. e.*, bulkheads of curved form. Bulkheads of this nature were referred to by Mr. Owens in his paper read before the Institution of Naval Architects last spring, and are used by the French in the battleships of *La Bretagne* class.

Armor was now, as far as he was aware, always placed inside the ship on a longitudinal bulkhead at a certain distance from the outer shell. It was easy to show, however, that as now ordinarily constructed, this form of protection is unsatisfactory. Usually the armor is of 1½-inch or 2-inch thickness, and is supported only by a system of light stiffeners, quite out of proportion with the strength and weight of the armor itself. Probably the stiffeners will give way under the explosive pressures long before the plating is seriously strained, and the bulkhead will be blown bodily inwards. But even if the stiffeners are of adequate strength, it is likely that bulkheads as now constructed will give way by opening at the seams and butts and along the boundaries. It is very difficult, heavy and costly to give sufficient strength to these lines of weakness. Let it be supposed, however, that this is done; then the armor plating itself, being plane, will ultimately give way by bending, cracking or tearing at the stiffeners long before it has had a chance to offer a resistance proportioned to its great weight and strength. On the whole, armor is ill adapted to resist gaseous pressures; it is much better suited to resist local forces of great intensity, such as those due to the impact of projectiles.

As regarded armor placed on the outer shell, Professor Hovgaard went on to say that in 1909 he wrote an essay on this subject to Jane's "Fighting Ships," where he gave a full discussion of this problem, resulting in the conclusion that if armor is to be used at all, it should be applied externally rather than internally. An explosion tends to expend its energy chiefly along the line of least resistance, a principle that is well illustrated in a gun. There the energy is almost entirely expended in giving forward velocity to the projectile and to the gases. The work done towards the rear by the recoil, where the resistance is much greater, is comparatively small, and laterally—*i. e.*, normal to the unyielding walls of the barrel—no work is done. Analogous conditions exist when a mine or a torpedo explodes in contact with the outer shell of a ship. If the side is unprotected it offers practically no resistance, and the explosive pressures will be relieved instantaneously by exhaust into the interior of the ship, where they may cause widespread destruction. If, on the other hand, we could offer a greater resistance at the outer shell than that due to the inertia of the water, the explosive energy would be entirely or largely expended upwards into the atmosphere, since the line of least resistance would then be found in that direction. We cannot, of course, prevent a hole being punched in the side near the center of the explosion, but by fitting armor on the side we may limit the size of this hole in a great measure. Only experiments can tell us to what extent this is possible, and how external armor will compare with internal armor. As already stated in his aforementioned essay, it is of the greatest importance that such experiments should be undertaken. In 1910 he contributed another essay to Jane's "Fighting Ships," in which he recommended to fit 4-inch external armor on the outer shell, and to make the bottom, as far as possible, plane or developable. He recommended a form of the bottom somewhat approaching to that of a flat-iron, in order to facilitate fitting the armor, but as Mr. Ellis now stated that this difficulty no longer existed,

it is best in that case to adhere to ordinary ship forms. Hence, by fitting armor on the outside there appeared to be a possibility of keeping the greater part of the explosive effects outside the ship by giving the gas pressures time to exhaust more completely into the atmosphere. There is the further advantage that a good support of the armor is obtained without extra expenditure of weight, since the system of transverse and longitudinal frames in the double bottom can easily be made to offer a very considerable resistance.

His conclusion was, then, that if armor is to be fitted at all, it should be fitted on the outside; but he believed that the "elastic" bulkhead offered a far better solution of the problem. A crude calculation and even a simple consideration would show that it is possible with light plating of curved form to obtain enormous strength against gaseous pressure. Plane surfaces are, of course, entirely unfit for this purpose. No one would think of constructing a steam boiler as a rectangular box with plane walls. Even with ¼-inch plating it is easy to construct a bulkhead that will resist a head of several hundred feet of water. Such a bulkhead might be fitted at a moderate distance, perhaps from 8 feet to 10 feet inside the outer shell, and still be sufficiently strong. One important condition is, however, that it shall be adequately supported by deep girders. The elastic bulkhead would, he believed, essentially solve the problem of under-water protection, but it might be advantageous, in addition, to give to the outer shell a substantial thickness—for instance, 1 inch—and to construct it of a tough, high-tensile material, capable of being caulked, and well connected at seams and butts. This, however, was again a question that could only be settled by experiments.

The Marquis of Bristol, in calling on Sir John Biles to reply to the discussion, regretted there was no torpedo admiral present to give his side of the question. Sir Reginald Custance and he himself were both gunnery officers. It was clear from the paper that it would be possible to fit protective under-water armor, but the interesting question was, Would this armor give the protection aimed at? In any case, he was afraid it would be necessary to retain the present speed and armament in conjunction with the new armor. It appeared to him, in a practical sort of way, that one should have an inner skin and some sort of cushion which would more or less damp out the explosion before it reached the armor. Finally, he thought it the duty of the Admiralty to carry out experiments on this question.

Sir John Biles, in reply, said that the paper had had the effect he intended when writing it. It would be agreed that no opinion had been expressed that the battleship should be eliminated. He thought this a fact worth recording in connection with the meeting. A second point was that it seemed to be agreed that some sort of under-water protection was possible—say 4 inches outside, or 1 inch inside and some outside, or some such arrangement. A third point was the desirability of doing this. That, he thought, must be left an open question at present. None the less when one remembered the screen of destroyers and cruisers round a fleet could be completely penetrated by submarines, which it never could by destroyers, the question of such protection became of great weight. The question might become acute in the near future, and he agreed with Lord Bristol that it was the duty of the Admiralty to consider the question very seriously. The consideration of the paper then terminated with the usual vote of thanks.

THE FOTTINGER HYDRAULIC TRANSFORMER.

At this stage of the proceedings the meeting was divided into two sections, and in the King's Hall, Dr. Föttinger read a paper on "Recent Developments of the Hydraulic Transformer," which we hope to publish in an early issue. Results were given of recent installations, and this, the

author claimed, led to the conclusion that the economy of this system of power transmission and reduction resulted in an economy higher than that of electric transmission, and only 4 to 5 per cent. lower than that of mechanical gearing for ahead motion for the same steam conditions. For reversing and maneuvering its power and economy were over 100 per cent. better. Furthermore, by eliminating the astern steam turbine, a decisive step in economy was obtained by utilizing high superheat on board ship. The chief features of the system were: (1) Increased speed and economy for all service conditions; (2) increased size of units both in ships and engines; (3) increased comfort and luxury for passengers and crew, due to entire absence of noise and vibration; (4) increased safety against danger, due to rapid maneuvering; (5) increased life of turbine blading, due to constant rotation and absence of water-hammer and boiler-priming. In so far as the turbine was concerned, temperatures of 650 degrees F. could be safely used, a temperature which was now common practice in large stationary power plants.

Mr. Summers Hunter, who opened the discussion, acknowledged the free and frank manner in which Dr. Föttinger had placed his valuable experience before the Institution, and observed that the paper bristled with suggestions and valuable information. There were a few points which appealed to him as one identified more with merchant engineering than with warship work. Reliability and efficiency were what they asked for. Warships passed their trials at high power, and after that it was only in the stress of battle, when the lives of those on board were at stake, that the machinery was run at its maximum rate. With the merchant vessel it was quite different. Day after day, voyage after voyage, long or short, continual speed must be maintained, and he was sure it must be the admiration of everyone to notice the regularity with which our largest Atlantic liners and long-distance vessels performed their work at what was practically their maximum power and speed. It might be that under seagoing conditions some efficiency might have to be sacrificed to secure the reliability for which shipowners asked. From the shipowners' point of view, the question of cost was of primary importance. He was afraid that it did not matter how much economy they offered the shipowner, he would like the vessel at the same cost as the preceding vessel. It was a difficult position to meet, but he ventured to say new conditions were prevailing, and that, as opportunities arrived, the shipowners who were up to date were not afraid to spend a little more money to get what was so desirable—economy and efficiency. These were the considerations which must be taken into account in appraising the value of power transmission systems. As regards superheating, although he had done much in its adoption in merchant ships, he feared that, for the present, 650 degrees F. was an excessive temperature.

Mr. R. J. Walker said that Dr. Föttinger was to be congratulated upon the success which had attended his efforts in the development of hydraulic transmission. The high efficiency which he obtained bore testimony to the good work he had accomplished in the transmission of power on hydraulic lines. He (Mr. Walker) was afraid that time would not permit him to deal fully with the many points raised in the paper, and the arguments used by the author in support of hydraulic transmission when compared with direct coupling of turbine engines to the propeller shaft or with mechanical gearing, and he would therefore confine his remarks to the few more important questions.

As regards efficiency, he thought it was generally accepted that the loss due to transmission alone was at least 8 to 10 per cent. greater with hydraulic transmission than with mechanical gearing. Attempts were made to reduce this difference to about half the amount by certain estimates of losses and gains which might be summarized as follows: (1) Windage losses of astern turbines when revolving in the ahead direction. (2) Loss due to thrust block. (3) Increase in the over-all efficiency with

hydraulic gears by using the heated water of the transformer to increase the temperature of the feed water.

With regard to windage losses in astern turbines, Mr. Walker said this question was fully dealt with in the discussion on Sir Charles Parsons' paper on "Mechanical Gearing for the Propulsion of Ships," read at the spring meetings of this Institution last year; but he would like to refer to an experiment which had recently been carried out at the Turbinia Works, Wallsend, by Mr. Cook (one of his colleagues at the works), on the windage loss of astern turbines in a geared installation recently constructed. The arrangement of machinery consisted of one high-pressure and one low-pressure turbine, with an astern turbine incorporated in the exhaust casing of the low-pressure turbines, the turbines being coupled to the propeller shaft by means of mechanical gearing. The total ahead power transmitted to the propeller shaft was 3,600 shaft horsepower. The revolutions of the turbines were 1,486 per minute, revolutions of propeller shaft 90, so that the ratio of gear was 16.5 to 1. The astern power was 60 per cent. of the ahead power (with the same quantity of steam). A new rotor was constructed carrying only astern blading and rotated in the fully-bladed turbine casing at varying speeds and vacua. The power was supplied by an electric motor and measured in the usual way. The results showed that with the turbines revolving in the ahead direction at a speed of 1,500 revolutions per minute, the loss was 10½ horsepower, or 3/10 of 1 per cent., with a vacuum in the condenser of 28 inches, and 21.5 horsepower, or 6/10 of 1 per cent., with a vacuum of only 26 inches, thereby confirming the figure given by Sir Charles Parsons in his reply to the discussion on the paper already referred to—namely, that when going ahead the astern turbines are revolving in the vacuum of the condenser, and under such conditions the loss was not more than ½ of 1 per cent. This result also confirmed Mr. Allan's experiments on windage loss of astern turbines.

With regard to the second point, in the later ships fitted with mechanical gearing pivoted thrust-blocks were employed, thereby reducing the losses in thrust-block friction to about 1/10 of 1 per cent., practically a negligible quantity. As to the third point, in most of the modern turbine vessels the exhaust steam from the auxiliary engines was utilized for heating the feed water. The quantity of exhaust steam available was in most cases quite sufficient to increase the temperature of the feed-water to 200 degrees or 220 degrees. Referring to the question of the regeneration of heat, Dr. Föttinger gave the increase in over-all efficiency of the transformer due to feed heating as 1.5 to 2 per cent.—this implied a loss in the transformer of 7½ to 10 per cent. of the brake horsepower of the turbine. It was also said that for poorer efficiencies even 3 to 4 per cent. more could be gained. By a simple calculation it followed that if it were possible to obtain more than double the increase in the efficiency due to this regeneration of feed heating, there would be in these cases double the initial loss in transmission.

Referring to the question of propeller efficiency, it had always been admitted that with direct-coupled turbines some sacrifice had had to be made in propeller efficiency as well as turbine efficiency, and that it had been necessary to compromise between the two. It was true that in some large-powered high-speed vessels propulsive efficiencies with direct-driven turbine propellers had been obtained approaching that of vessels with piston engines; but in making any comparison of propulsive efficiency, as naval architects well knew, a very careful examination of the conditions and factors affecting propulsive efficiency required to be made. An error frequently encountered in the early stages of the development of the turbine engine was to compare the propulsive efficiencies between a turbine-driven ship and a vessel with piston engines, taking the shaft horsepower in the former case, and the indicated horsepower in the latter, whereas a

correction should have been made to bring the piston engine to a common basis of shaft horsepower.

Generally speaking, it was quite possible with reduced revolutions of propeller to obtain an increase in propeller efficiency varying from 5 per cent. to at least 12 per cent. in the different classes of ships where the direct-driven turbine had hitherto been successfully applied. With mechanical gearing, where the ratio of gear was not limited as in the hydraulic transformer, then full advantage could be taken of this increase in propeller efficiency to reduce the shaft horsepower necessary for a given speed. This reduction of power, together with the increase obtainable in the efficiency of high-speed steam turbines, permitted of a considerable reduction in boiler power, size of auxiliaries, and condensing plant.

With the ratio of gear to which the hydraulic transmitter was limited it would appear that it was confined to a somewhat narrow field of work, inasmuch as it was not possible to secure, in the majority of cases, the accommodation necessary between the speed of the turbine and the speed of the propeller for maximum efficiency of each. There was therefore, in addition to the loss in transmission, a further loss in the propulsive efficiency with hydraulic transmission when compared with mechanical gearing, and the difference in over-all efficiency, when referred to in "knots run per ton of fuel," had been found to be very considerable in designs for war vessels.

He did not think that Dr. Föttinger had established any of the claims set forth in his conclusions. The question as to whether larger units incidental and necessary with hydraulic transformers were an advantage he thought was very much open to doubt. The placing of turbines in series on a common gear wheel, instead of an independent turbine, had many advantages in favor of its recommendation; it was more economical in steam consumption, and the units were much smaller and more accessible, and in the event of a turbine being temporarily deranged, suitable pipe connections could be arranged for the working of the other turbine. In recently-constructed gears, which had been cut on the "creep" principle, noise had been practically eliminated. There was no difficulty in arranging for an astern power of 75 per cent. that of the ahead, should it be desired; but for all practical purposes it had been found that 60 per cent. of the ahead power was ample for any condition of maneuvering, and all recent designs of geared turbines provided for an astern power of at least 60 per cent. of the ahead for the same quantity of steam. Dr. Föttinger had suggested that astern turbines were a source of trouble. This was not the case. No trouble whatever had been experienced by the heating up of the ahead blades when driven in the opposite direction at full speed. The ahead turbine was connected to the vacuum of the condenser when going astern. It was observed in the illustration accompanying Dr. Föttinger's paper that an additional transformer was required for astern purposes in lieu of the astern turbine.

There was no difficulty in using superheated steam in geared turbines, either ahead or astern, provided suitable materials were employed in the construction, such as cast steel, instead of cast iron, for the high-pressure parts of the turbines. As a matter of fact, there were several geared-turbine installations under construction, arranged for superheat of 100 degrees to 150 degrees F.

Dr. Föttinger, in replying, asked if Mr. Walker had seen the transformer plant at work, to which Mr. Walker replied in the negative. Continuing, Dr. Föttinger said he was afraid that Mr. Walker spoke on figures which had now been surpassed by the new results. There were, he said, other ways of looking at an engine besides the 5-per-cent. economy, and that from this point of view the hydraulic system merited consideration. He did not claim that what he had propounded was the solution for all

questions and problems, but he proposed to show in future that this contribution, though a modest one, was a positive contribution to international science.—"Engineering."

THE FUTURE OF THE SUBMARINE BOAT.

Keen interest has been reawakened in the subject of the relative importance of the submarine boat and the battleship by the publication in the "Times" of a letter from Admiral Sir Percy Scott, because this distinguished naval officer has taken the view that the "building of any more battleships now will be a misuse of money subscribed by the citizens for the defence of the Empire," as he can see "no use for battleships and very little chance of much employment for fast cruisers." For a long time it has been recognized that the submarine boat must take an increasingly important part in war tactics, and there is no doubt that in those peace maneuvers where war conditions are simulated the submarine boat has taken a place of growing significance and success. But the storm of criticism which Sir Percy has raised in the columns of our contemporary shows that the change he advocates now must be of gradual growth, and not a *volteface*, and that the acceptance of his view, as quoted, would be a grave danger to the defence of the Empire. It certainly cannot be said that he has adduced convincing reasons for the complete change in naval policy which he advocates.

His view is that at the beginning of hostilities submarine boats will be able effectually to bottle up in harbors all surface craft, and that a "battleship is not immune from attack even in a closed harbor, for the so-called protecting boom at the entrance can easily be blown away." Thus, if a battleship is not safe on the high seas or in harbor, he asks: "What is the use of a battleship?" Moreover, he says, submarine boats are difficult to destroy, because "it is difficult to attack what you cannot see." Thus he contends that what we require is an enormous fleet of submarines, airships and aeroplanes, and a few fast cruisers, provided we can find a place to keep the latter in safety during war time. We are at one with Sir Percy Scott in his view that we should have a great fleet of submarine boats, but until other Powers decide to cease building battleships and other surface craft, it would be fatal for Britain to discontinue the present policy so far as these are concerned. A "Naval Officer," who has written most cogently on the weaknesses of Sir Percy Scott's contention that we must cease building battleships, controverts the premise on which Sir Percy founds his conclusion. The booms protecting harbors have never been destroyed by submarine boats, and although torpedo-boat destroyers have been able to enter harbors thus protected, they have done so by "jumping the boom," with considerable damage to themselves. Moreover, if the enemy's surface ships succeeded in escaping from harbor, there would be serious menace to Britain, and particularly to our food supply, in consequence of the depredations which they might effect when unopposed by vessels of equal modernity and corresponding speed. No doubt for a few years our present surface boats would equal in tactical quality those of the enemy. But if, at Sir Percy Scott's injunction, we ceased building such vessels, while other Powers continued to do so, we should be placed in jeopardy in a very short time. It may not be easy to fight submarine boats except by their opposites; but by reason of their comparatively low speed, they would never overtake a surface boat which might escape from harbor. Besides, it has not been established by Sir Percy Scott that the torpedo, practically the only weapon of the submarine boat, would be effective. Again, the radius of action of such boats when submerged is very limited, not much more than 100 miles, so

that in taking a voyage across the North Sea they would have to proceed "awash," and would then be subject to attack by torpedo-boat destroyers and other surface craft, and by aerial vessels.

Our intention in discussing this matter is not so much to consider the tactical qualities, but to regard the problem of the future potentialities of the submarine boat from a mechanical standpoint. Until such craft are made more powerful, are given a higher speed, and have a much greater radius of action, their success must be limited, even in attacking vessels in harbor, particularly in the presence of the latest system of submarine-mine defence. All of these qualities call for increased dimensions, which increase their cost and reduce their handiness, especially in harbors and comparatively shallow waters. That progress is being made in the design of submarine boats to attain the advantages desiderated is undoubted. The British Admiralty are fully alive to the possibilities of this new type of craft. They are vigilant in their study of progress in other navies, and are acting with enterprize in the encouragement of developments, particularly in respect of propelling machinery and torpedo design. The interests of the nation preclude us from giving information regarding the latest British experimental vessels, but it may be said that in the one case the size exceeds that of any submarine boat yet ordered, and that in another case the aim is for higher speed. When these two vessels are completed their trials will disclose to the technical officers of the Admiralty the lines along which further development may be made.

First, in regard to size, it may be said that the largest of the German boats nearing completion has a displacement on the surface of 750 metric tons, and submerged of 900 tons, the length being just over 214 feet. It is propelled by two sets of Diesel engines, together of 4,000 brake horsepower, working twin screws, and it is anticipated that the speed on the surface will be about 20 knots and submerged about 10 knots. Russia is understood to be building a vessel of considerably over 1,000 tons, and proposals for ships of as much as 1,700 and 2,000 tons displacement are being considered by other Powers. These larger vessels will be able, of course, to carry a greater offensive armament, either by increasing the number of torpedoes, or by fitting larger guns with disappearing carriages, for which cavities are formed in the deck. It is understood that, so far, only 12-pounder guns are contemplated. If, however, four guns of 4-inch caliber were adopted, the displacement would require to be increased, while the adoption of 6-inch guns would necessitate an increase in displacement of 18 per cent. over the vessel with 12-pounder guns. Increase in size, too, demands greater power, even if the speed be constant, and the aim is to get still higher speeds. So far practically all modern submarines are propelled by heavy-oil engines, and little difficulty need be experienced in supplying to a submarine boat engines of 4,000 or 6,000 horsepower without increasing to any appreciable extent the size of the individual cylinder. Moreover, progress has undoubtedly been made in the reliability of engines with cylinders of much higher power, and one may anticipate in the early future cylinders of 1,000 horsepower. No trouble need be anticipated on this score excepting that the size of the ship must go on increasing if higher speeds are desired than are at present anticipated.

There is, however, a growing disposition to experiment with steam turbines in submarine boats, and it will be remembered that France many years ago adopted a flash boiler for developing steam for driving submarine boats, but the results were such that the system was discontinued, largely because of the time required to damp down the boiler preparatory to diving. With the perfection of oil-fuel-burning apparatus for water-tube boilers, and the great gain in the introduction of the steam turbine, opinion in France has undergone a change, and at the present time there are being built a large number of submarine boats, with express boilers of the Yarrow type, having specially small tubes, in order that the water

contents may be less than is the case even with destroyers. The turbines are of the Parsons type, to run at very high speed, gearing being introduced between the turbines and propellers. The four submarine boats of this type most advanced are those built at Rochefort, of 900 tons displacement, and with turbines to give 4,000 shaft horsepower—namely, 2,000 on each shaft. Two others are building at Cherbourg, and in this case the displacement is 950 tons, the power being 5,000 shaft horsepower. There will be electric motors for propulsion when submerged, as in existing vessels. It is understood that even larger steam-driven submarines are about to be laid down, the power of the turbine machinery being 10,000 shaft horsepower, and the speed anticipated over 20 knots. It is under consideration in this latter case to fit, for low-speed running, oil engines for cruising on the surface. This would conserve the oil-fuel supply, as the oil engine has a less consumption than the steam installation. Thus the radius of action at cruising speed would be very greatly increased. It is a case of balancing advantages and disadvantages from the weight point of view. It remains to be seen whether the oil engines for cruising at low speed would save, under given strategic conditions, an amount of fuel corresponding to the excess consumption at low speed of the steam engine, and thus compensate for the weight of the oil engine, which must be dead-load when running at full speed. But there still remains the fact that greater power of offensive, higher speed, and wider radius of action—all necessities of the case—involve increase in size.

Every increase in the size of a submarine boat not only adds to its visibility when running awash, but increases the time and distance required for disappearing if the vessel has to dive, and not to sink on an even keel, unless the angle at which the vessel dives is made much steeper. The difficulty in such case has reference to the electric storage batteries, and to other vessels containing liquids, where alterations in the level introduce disturbing influences. The acuteness of the angle of dive, too, intensifies the difficulty of subsequently bringing the vessel to an even keel, and increases the danger of the vessel striking the bottom, a danger which has involved the loss of one or two submarine boats of comparatively small size. Greater depth of water is required for such operations, so that only small vessels can be used in attacking ships in harbor.

These various developments in the mechanics of the submarine show that progress is being made, but the problems have so many variants and demand such careful experimental research that it would be a mistake to hasten unduly those responsible for the evolution of design. What is demanded on the part of our naval authorities is to move with as much rapidity towards improvement as is consistent with the ensurance of reliability in each vessel built, and at the same time to maintain as much secrecy as possible. From the mechanical point of view the submarine is undoubtedly in a transitory state. To accept any design at the moment, and build a great number of vessels in excess of the requirements as measured by our opposing forces, would be unduly to tax the citizens' responsibility for the defence of the Empire, with the extreme probability that the vessels thus built would be obsolete in a very short time. For this reason we advocate an active policy by the Admiralty, but would regard as a tactical blunder the neglecting of the building of ships-of-the-line, particularly when all other Powers are continuing to add to their fleets battleships and cruisers.—"Engineering."

COMMENT.

Submarines are defensive weapons of naval warfare incapable of operating except in a restricted field, and require for their continued operation the presence of a tender. Air craft and fast scouts are auxiliaries whose province is to gain information. Neither of the above class of naval craft

are offensive weapons capable of holding the sea by themselves. They are subsidiaries, very useful at times, but in the absence of a fleet of capital vessels they would be of comparatively little use to secure and maintain the "command of the sea." This class of craft by themselves might play a hide-and-seek kind of warfare which might be interesting but never decisive. The command of the sea will be controlled by capable capital vessels fitted to withstand any condition of the elements and able to engage any fighting craft of an enemy. To build a so-called harbor-defensive, commerce-destroying navy is only wasting time. The "command of the sea" is the essence of success in naval warfare. The fleet must be built with this end in view. Anything short of this is a dangerous makeshift.

Submarines and aeroplanes are interesting and wonderful craft; they are, however, as yet very far from being reliable, their offensive qualities and capabilities are extremely limited. The large submarines proposed will cost about one-fifth of what a battleship will cost, so that the *enormous* fleet of submarines cannot be secured except at an increase in the naval budget. The capital ship, capable of keeping and maintaining the sea, has been the decisive instrument in naval warfare ever since the dawn of history, and it is likely to continue so. With the advent of the torpedo boat, half a century ago, the doom of the large fighting vessel was predicted; but, on the contrary, the capital vessels are larger and stronger than ever before, and a nation without powerful capital ships cannot be considered as having a real navy.—H. C. D.

INTERIOR PROTECTION AGAINST TORPEDOES AND MINES.

Because of the striking lessons furnished by the Russo-Japanese war, and because of recent advance in the automobile torpedo, as well as of more extensive use of the submarine mine, all navies have been striving to improve upon the interior protection of ships against torpedoes and mines. The means to the one end adopted in the various countries, differ, and it will be interesting to investigate them.

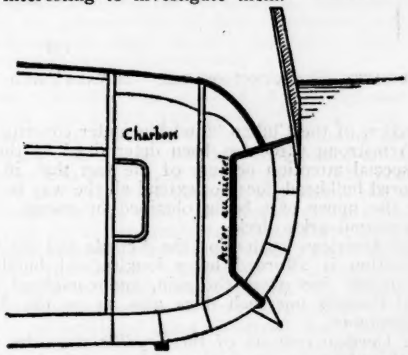


FIG. 1.—UNDERWATER CAISSON OF THE "DANTON" CLASS.

On the English battleships of the *Orion* and *King George V* types, a longitudinal bulkhead runs, close to the ship's side, along the magazines and engine room, very much like the under-water caisson of our *Danton*

class. This bulkhead is made up of two thicknesses of sheet steel of high resistance, of a total thickness of two inches; but, unlike the practice in the case of our *Danton* class, where the caisson is continuous, the bulkhead of the *Orion* classes is interrupted abreast the stoke holes, where it is continued by only a simple watertight bulkhead twenty feet distant from the ship's skin, the space between the skin and the bulkhead being occupied by the coal bunkers. The cause of this arrangement is the current opinion that coal constitutes an effective protection, a ten-foot layer being the equivalent of one inch of steel.

On the cruisers of the *Lion* class, the boilers being in much greater number, the stokeholes have had to be made wider, the runways are as long as fifty feet, and the longitudinal bulkhead is continuous from end to end, though its thickness is decreased from two inches to one inch abreast the coal bunkers.

These general arrangements for protection are common to all English shipyards. So the Japanese cruisers of the *Kongo* class (27,000 tons), under construction (October, 1913) in the Vickers yards, have been given a similar longitudinal protection, with an addition of an armored covering, one and a quarter inch thick, in the vicinity of the bunkers—an arrangement that is seen also on the Argentine battleships *Moreno* and *Rivadavia* under construction (October, 1913) in the United States.

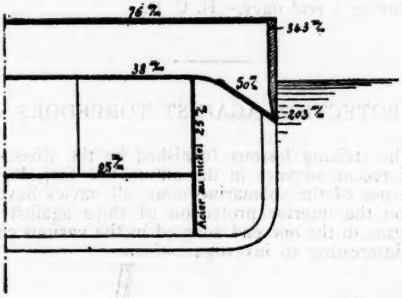


FIG. 2.—UNDERWATER PROTECTION OF THE "NEVADA" AND "OKLAHOMA."

The main section of the Chilian battelship under construction (October, 1913) at the Armstrong yards has been determined by the same desire; but it merits special attention because of the fact that, in order to gain space, the armored bulkhead does not extend all the way to the top, armor protection for the upper part being obtained by means of an armored portion of the second orlop deck.

On the recent American battleships, the *Nevada* and the *Oklahoma*, under-water protection is afforded by a longitudinal bulkhead one inch thick, located sixteen feet from the skin, and completed at the bottom by a horizontal flooring one inch thick also, as on the Argentine ships *Moreno* and *Rivadavia*.

On the large German cruisers of the *Seydlitz* class the armored bulkhead is vertical and varies in thickness from 1.18 to 1.97 inches, the greatest thickness being abreast the magazines. Located thirteen feet from the skin, this bulkhead runs from the forward turret to the aft turret, having its ends against armored athwartship bulkheads .79 inch

thick, and extends above the protected deck to the gun deck. It is almost the same arrangement as that used on the *Kaiser*.

Special mention is due the Russian *Impératrice Marie* class, in which protection against torpedoes is afforded only by watertight subdivisions, or compartments.

In order to protect themselves against flooding as a result of a breach in their bottoms and to avoid the inconveniences of an exaggerated roll, the holds of the new Russian battleships have only athwartship compartments, without middle bulkheads, which occur only in the (otherwise too spacious) engine and boiler rooms, and these are limited to the minimum requirement.

Heretofore, in France, we have favored the armored bulkhead near the ship's side and it is from that that has developed the caissons for longitudinal protection provided in the bottoms of our *Danton* class.

FIG. 3.

FIG. 3.—ELASTIC BULKHEAD OF THE "FLANDRE" AND "BRETAGNE" CLASSES.

Are those arrangements really efficacious? It would seem that for the present one may not be at all sure of it. Experiments made in France (Brest and Lorient, *Henry IV* and *Danton* caissons) as well as abroad (Chatham, England, 1910; Bremerton range, United States, (1911-12) have left the matter in considerable doubt. It seems, however, that our recent arrangement, the vertical armored bulkhead, called "elastic bulkhead," ought to give the best result in all respects. This bulkhead, with which our recent ships, *Bretagne, Flandre,* etc., are provided, is made up of three thicknesses of sheet steel, about .4-inch thick each, of which two are joined, while the third forms, between uprights, cells of 7.8-inch* thickness, as illustrated in Fig. 3. The most recent experiments in this matter have demonstrated that the foregoing arrangement is clearly more efficacious than the arrangement of three thicknesses of sheets of like thickness superposed one upon another, and more efficacious also than the protective caisson of the *Danton* class.

A last system, however, has just been extolled as especially efficacious and is being very generally studied. It is the arrangement originated by Mr. Wotherspoon, which has been employed in the case of the *North Carolina* and the recent American battleships, including the *Pennsylvania*.

Mr. Wotherspoon's plan is to introduce compressed air in order to stop the flow of water into a damaged compartment. The plan assumes that all the bulkheads are perfectly watertight, and that is the only weak point that can be found in it. In order to diminish the pressure on the bulkheads, compressed air of less pressure is introduced in the compartment which immediately surrounds the damaged one; and a third compartment, which covers the two others, receives air at a pressure equal to that which the watertight bulkheads can withstand. In the American experiments the air pressure varied, in this way, from four to fourteen pounds per square inch, no bulkhead being subjected thereby to excessive pressure.

In order to gain entrance to the damaged compartment, one passes from one compartment to another by means of a series of locks similar to our ordinary manholes. It would seem, therefore, easy to construct the compartment system of large ships to satisfy those desiderata—all the more,

*The text reads 200 mm.—Tr.

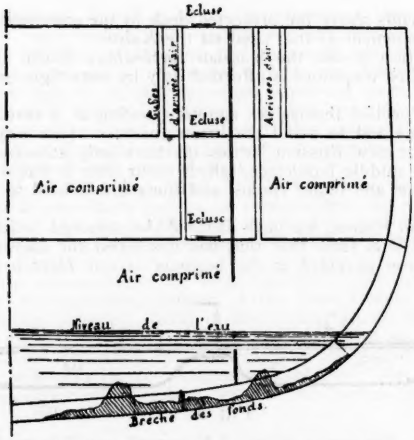


FIG. 4.—THE WOTHERSPOON SYSTEM OF UNDER-WATER PROTECTION BY MEANS OF COMPRESSED AIR.

since Mr. Wotherspoon uses for the introduction of the compressed air, the ventilating-pipe system already installed for the conveyance of fresh air to the compartments.

The advantages of the American system are readily seen; for, aside from possible protection against inflow of water, it makes it easy to test the compartment system of a ship for watertightness—a test which up to now has never been made in practice. Furthermore, the new installation will permit rapid fighting of fire in a compartment by means of introducing into it, instead of compressed air, an extinguishing gas, such as carbonic acid.—Published J. U. S. A., translated from "Le Yacht" (Paris).

GEARED TURBINES.

The following is a translation from the "Moniteur de la Flotte" of May 16, 1914.

The use of geared turbines, Parsons system, of which we have spoken on several occasions, has just received a very great extension, their adoption having recently been decided for a hundred war and merchant ships. Amongst the first is our squadron torpedo boat *Enseigne Cabolde*, of 22,000 H.P. The total horsepower transmitted by the same system is now not less than 700,000, and there are units of which the power attains 40,000 on two shafts, the power of the turbines being distributed between four pinions, each transmitting 10,000 H.P.

The efficiency of this system of transmission is so high (at least 98 per cent.) that no other system can bear comparison with it. This result has been obtained by the solution of the problem of the exact cut of the gearings. Machines of the latest type, capable of performing this work, are already being mounted in France.

The principal advantages of the system are: absolute mechanical sim-

plicity, efficiency of almost 100 per cent., as we have just stated, and illimited proportioning of the transmission, permitting to adopt, for the propeller as for the turbine, the speed of rotation that corresponds to maximum efficiency. Thus, for the propeller of cargo boats, 60 to 70 revolutions are found to give the best results, and for battleships, 180 revolutions, as in the case of alternating engines. Good propellers are driven by turbines of 2,000 to 3,000 revolutions, the consumption of steam corresponding to that of generating groups on shore. It may be added that, if the old gearings were somewhat noisy, the new ones are silent.

It is regrettable for its ingenious inventor that the Föttinger system of hydraulic transmission was known so late. Had this apparatus existed ten years ago, it could have rendered important services while awaiting the improvement of gear-cutting machine tools. But at present the Föttinger apparatus, notwithstanding all its ingenuity, finds its way blocked, for with its efficiency or 88 or 90 per cent. it encounters the 98 per cent. of the gearings. Its debut was brilliant, but it now receives but few orders in comparison with its rival.

Unfortunately for the hydraulic system, its inferior efficiency is not its only defect; it suffers from its connection with the shaft of the propeller not being positive, but dependent on the filling up of the water circuit, which is effected by a high-speed rotative pump running continuously. Consequently the possibility of the machine driving the propeller is dependent on an auxiliary apparatus; in addition, as the steam turbines of these installations are irreversible, it is necessary to empty the water circuit for reversing and then to fill a secondary circuit. It is unnecessary to dwell longer on the disadvantages of these complications.

We mentioned above the illimited proportioning of transmission by gearing, but this is not the case with the hydraulic apparatus. The transmissions known are about in the proportion of 4.5 to 1, and their defenders claim only the possibility of going from 6 to 1. It results that, in the greater number of applications observed, either the propeller turns too quickly or too slowly to realize the best result. The comparison has been made in particular between the passenger steamers *Hantonia* and *Normannia* (gearing), and the only important ship fitted with the Föttinger apparatus and which still navigates, the *Königin Luise*. These are ships of analogous dimensions, which have developed in round figures 5,000 H.P. for 22 knots speed. Yet the propellers of the *Königin Luise* are not those of a ship with reciprocating engines, for they make 450 revolutions, instead of the 300 revolutions approximately of the *Hantonia* and *Normannia*. Any engineer will immediately see how much more efficacious are slow propellers and how much greater is the proportion of power of shafts transmitting it by axial thrust.

There is another point in this comparison and to which we will refer, and that is that it has been maintained by some that the consumption of steam was the same in the two cases, without bringing into account the fact that the boilers of the *Königin Luise* are fitted with steam superheaters, while the *Hantonia* and *Normannia* use saturated steam. If we count 7½ per cent. of actual superiority for the *Hantonia* and the *Normannia*, from the fact of this superheating, and again 7½ per cent. for the better thrust of the slow propellers, we shall get a very moderate and sensibly exact evaluation of the effective difference of efficiency between the apparatus with gearings and the hydraulic system, by fixing this difference at 15 per cent. of the total.

NOTE.—This comparison may profitably be considered in connection with Mr. E. N. Janson's article "Transmission of the Propulsive Power in Ships," in the May, 1914, number of the JOURNAL OF AMERICAN SOCIETY OF NAVAL ENGINEERS.

RENEWING DUMMY AND GLAND STRIPS IN A PARSONS STEAM TURBINE.*

By N. I. Mosher.†

The method of renewing the dummy and gland strips in a Parsons steam turbine presented in this article outlines the shop practice of the Boston Navy Yard, and a method of procedure is also described which can be followed with satisfactory results when it is not convenient to dismantle the turbine and send it to the shop for repairs. Part of the section of the rotor with the dummy rings is shown at *A* in Fig. 1, and the dummy-ring strips are shown at *B*. The strips are made of hard bronze and act as a baffle and packing between the revolving rotor and the fixed cases. These dummy strips become worn from unequal expansion be-

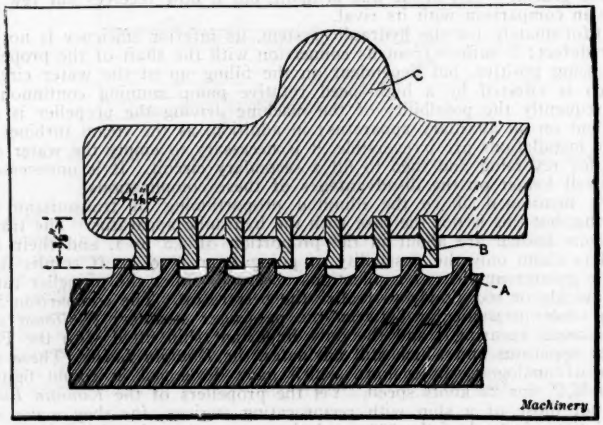


Fig. 1.—Arrangement of the Gland Case Dummy-Ring Strips and Dummy Rings.

tween the cases and rotor or from improper thrust adjustment, causing the strips to rub against the dummy rings. The adjustment between the dummy rings and the strips is ordinarily 0.012 inch. By the proper manipulation of a micrometer instrument, the correct location of the dummy rings in relation to the dummy strips can be determined while the turbine is in motion with a great degree of accuracy. The turbine

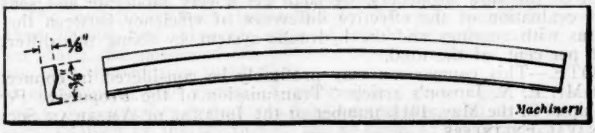


Fig. 2.—Detail of One of the Finished Dummy-Ring Strips.

*For additional information on this subject, see "Re-blading a Parsons Steam Turbine," published in the December, 1913, number of "Machinery."

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considered in this article has thirty rings, which are cut into the rotor to a depth of 3/16 inch, and the rings are 3/16 inch wide on the steam-entering end of the rotor.

The dummy-ring strips are secured in a casting which, in turn, is secured to the inside end of the turbine cases and machined diametrically true from the axis of the journals. These strips are 4 inches long and rectangular in shape. Fig. 2 shows a detailed view of one of the strips. The following method of renewing these strips was adopted. Standard plates of bronze 24 by 48 inches in size were sawed into strips 4 inches wide, making eleven pieces 24 inches long by 4 inches wide. Eight of these pieces were next secured to the boring-mill platen, running out radially from the center. Then a tool was forged and its end machined to the desired shape, as shown in Fig. 3; and the tool holder was moved the required distance on the rail to give a diameter of 31-3/16 inches. The tool was then fed down into the revolving pieces on the boring-mill platen, forming and cutting off eight of the required shaped strips. With the tool remaining in its original position, and by simply unstrapping the brass plates and moving them out the required distance, another set of eight strips was cut off, and so on until the plates were entirely cut up. This method wastes very little stock and the operator can easily cut 150 pieces in eight hours.

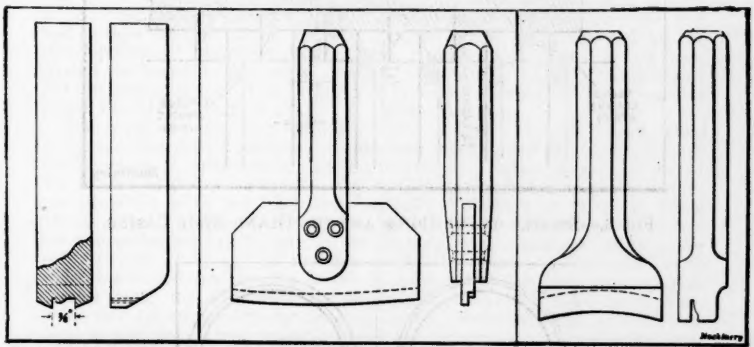


Fig. 3. Tool used for machining the Strips in the Boring Mill

Fig. 4. Type of Tool used to set the Finished Dummy Strips in the Gland Case

Fig. 5. Type of Tool used to insert the Finished Gland Rings

The variation in the thickness of the bronze plates was found to be from 0.001 to 0.007 inch, and to overcome this a sizing die was made which sheared the pieces all to one thickness, namely, 0.125 inch. This completed the machining operations, leaving the pieces finished all over to the proper thickness and diameter. The grooves in the gland casing *C*, Fig. 1, were approximately 0.123 inch wide, or just enough smaller to afford a snug driving fit when the finished strips were forced into them. For performing this operation, a set was machined to the same radius and length as the dummy strips, as shown in Fig. 4. These strips are set about 0.012 inch apart to allow for expansion. After having the 600 strips forced into the grooves, a set was used to calk the metal and fasten the strips more securely.

Having completed the dummy strips, we now turn to the gland strips. Fig. 6 shows the rotor-spindle strips and the gland-strip casing and strips. It will be noticed that the gland strips are of a different design (see Figs. 7 and 8) from the dummy strips. The edges are machined to a knife edge and the spindle strips just touch the inside of the case that sup-

ports the fixed strips; the fixed strips, in turn, just touch the spindle, less a clearance of 0.002 inch. The material for the gland strips is purchased from the mills in rectangular shaped pieces ⅛ by ⅜ inch in size, rolled up in coils about the diameter of the spindle and the gland cases. These coils are cut up into the required pieces, which are forced into the grooves of the spindle and gland cases. Ordinarily about five sections to each ring are set in with a clearance of 0.012 inch between each section, which is to allow for expansion. Having the sections securely calked in both the spindle and cases, they are then machined to the proper diameter and formed, as shown in Fig. 6. The casing that holds the gland strips is

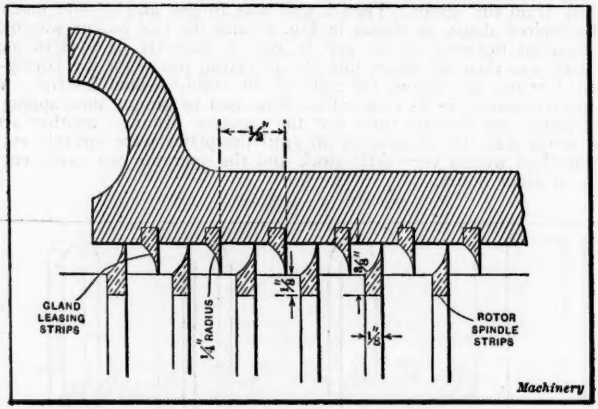
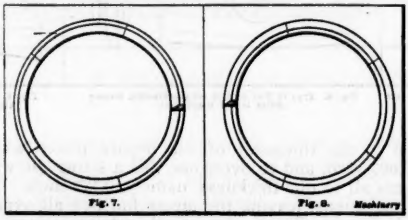


FIG. 6.—SPINDLE OF THE ROTOR AND THE GLAND-STRIP CASING.



FIGS. 7 AND 8.—FIXED GLAND RINGS AND SPINDLE GLAND RINGS.

detachable from the main turbine case and can be set up in halves on either a horizontal or a vertical boring mill, enabling the machining operation to be performed very satisfactorily. The operation on the spindle is purely a lathe job.

The preceding paragraphs describe the method followed when a turbine rotor and cases are delivered to the shop. When the work is to be done on board ship, however, without the use of a full equipment of power-driven tools, the following operations are required: First, cut the gland strip stock, ⅛ by ⅜ inch in size, into rings of the proper diameter. Second, with a suitable holder on the lathe faceplate, finish these rings to

the correct diameter and form. Third, cut the rings into the required number of pieces (see Figs. 7 and 8); they are then ready for inserting in the spindle and gland cases. For this purpose two tools are made, one machined as shown in Fig. 5 for the spindle rings, and the other machined to fit the gland rings for the cases. Experience has proved that these tools stand up best when made from a soft steel of suitable carbon that will toughen under oil tempering; and with careful manipulation of the tools, a very satisfactory job may be done by this method without sending parts to the shop.—"Machinery."

WESTINGHOUSE MARINE EQUIPMENT.

SYNOPSIS—*Description of the marine steam turbine, reduction gear, bridge control and auxiliaries as built by the Westinghouse Machine Co., with special reference to the installation on the U. S. collier "Neptune."*

In the application of steam turbines to marine service, certain problems are encountered which are not present in land practice. Among these may be mentioned the desirability of relatively low propeller speeds, whereas it is desirable to run the turbine at high speed to keep down the size and weight and to attain greater economy. This condition led to the development of the Melville-Macalpin reduction gear, which has now passed the experimental stage, and has successfully met the requirements for the transmission of large powers in actual service, the most notable installation being that of the U. S. collier *Neptune*.

The results of the trials of the original equipment of this vessel, while demonstrating the adaptability of reduction gears to marine service, showed the necessity of modifications of the turbine and reduction gear. One of the important points brought out by the trials was that the revolutions of the propeller were too high, the original revolutions at 14 knots being 135 and those of the turbine 1,220. It was decided, therefore, to replace the propelling machinery, one of the changes being a decrease in propeller speed to 110 r.p.m. and an increase in turbine speed to 1,910 r.p.m. The following description applies to the remodeled arrangement and also represents what the Westinghouse Machine Co. has developed as a complete line of equipment for marine service, including the turbine, condensers and auxiliaries, reduction gear and dynamometer, and bridge control by which the turbine is under the complete control of the navigating officer.

TURBINE.

This is a combination impulse and reaction type, the high-pressure elements of both the ahead and astern turbines consisting of impulse wheels. The substitution of a high-pressure impulse wheel for reaction blading in marine turbines has two important advantages: First, it has a greater stopping torque, and, second, it permits nozzle control. Furthermore, it materially shortens the turbine and permits both the ahead and the astern turbines to be contained in one casing, thus eliminating cross-connections.

Although the impulse wheel is not as efficient as reaction blading, it is possible to so design an impulse wheel with two rows of blades that its efficiency will not fall off seriously when the steam velocity is only 2 to 2½ times the blade speed, and will remain nearly constant until the velocity of the steam reaches 4 to 4½ times the blade speed. Therefore, by the use of nozzle control the efficiency of the high-pressure element may be kept fairly constant over a considerable range of power and speed.

Fig. 1 shows the turbine with the stationary blade rings removed, and Fig. 2 is a section through the turbine. It will be noted that the spindle

is in three parts, bolted together. The first section carries the astern impulse wheel and reaction drum, the middle section the ahead impulse wheel and part of the ahead reaction drum, and the third section the remaining part of the reaction drum. As the effective mean diameter of the ahead and astern reaction sections are the same, a single dummy located between the two impulse wheels serves for both the ahead and the astern reaction sections. Any slight unbalanced end thrust is taken up by a Kingsbury thrust bearing.

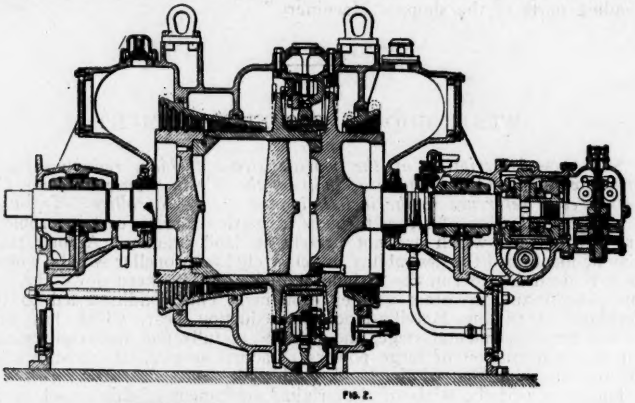


FIG. 2.

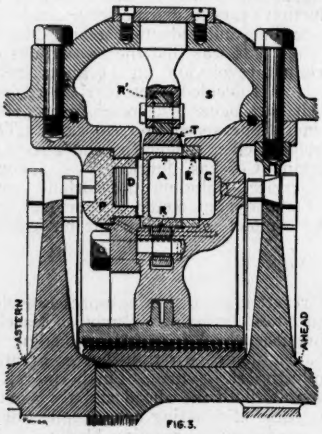


FIG. 3.

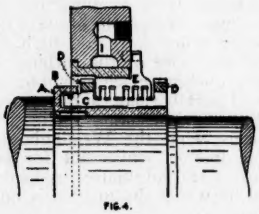


FIG. 4.

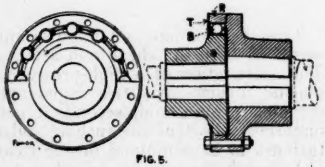
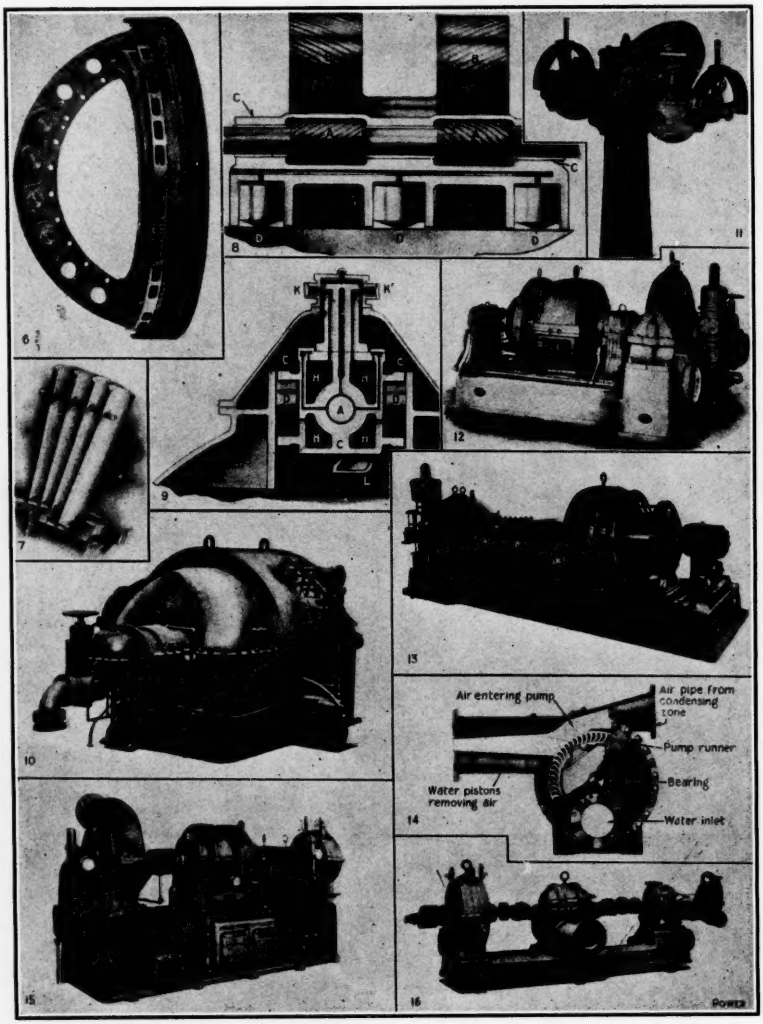


FIG. 5.

SECTION AND DETAILS OF WESTINGHOUSE MARINE TURBINE.

Fig. 2.—Longitudinal section through turbine. Fig. 3.—Nozzle valve and nozzles. Fig. 4.—Turbine glands. Fig. 5.—Flexible coupling.

Referring to Fig. 2, the valve connecting the astern impulse-wheel chamber with the condenser is provided to permit the escape of any steam leaking past the dummy when running ahead, without the necessity of its passing through the astern reaction blading and thus causing addi-



Turbine and Reduction-Gear Details and Auxiliaries.

Fig. 6.—Nozzle block. Fig. 7.—Large reaction blading. Figs. 8 and 9.—Reduction gear showing floating frame. Fig. 10.—Port turbine with oil relays. Fig. 11.—Bridge-control stand. Fig. 12.—100-kw. direct-current turbo-generator. Fig. 13.—300-kw. direct-current generator with geared turbine drive. Fig. 14.—Leblanc pump. Fig. 15.—Combined air and circulating pumps with geared turbine drive. Fig. 16.—Combined air, condensate and circulating pumps with direct turbine drive.

tional lost work. This bypass valve is operated automatically by a piston resisted by the spring which normally holds the valve open, as shown, but as soon as the steam is admitted to the first astern nozzle the pressure back of the piston brings the valve to its seat.

In Fig. 3 is shown the nozzle valve and nozzles. The valve *A* is of monel metal with a cast-iron seat *E*, the balancing pistons *D* and caps *P* being of bronze. The nozzle valve *A* is moved by a rack engaging with gear teeth in the ring *T*, and rollers *R* and *R'* permit easy movement of the valve. The main steam supply for the ahead impulse wheel opens into the space *S* in the lower half of the turbine cylinder and that for the astern wheel into a similar space in the upper half.

One of the ahead nozzle blocks and the sliding valve are shown partly assembled in Fig. 6, also four of the balance pistons in place. The turbine glands are a modified type of labyrinth packing, as shown in Fig. 4, consisting of a brass sleeve *A* on the shaft in which fits a strip ring *B* packing the sleeve *C*, held by the rings *D*, and which rotates with the shaft. End movement of the sleeve *C* relative to the shaft is permitted so that the collars which fit into the bushing *E* with a few thousandths clearance will not bind nor press heavily against *E* when the spindle moves endwise from expansion. Steam for sealing and lubricating the labyrinth is supplied through the inlet *I*.

The stationary reaction blades are held in cast-steel rings doweled to the turbine cylinder, Fig. 7, showing the method of attaching the large reaction blades.

In order to permit the gear pinion to float longitudinally without imposing any end thrust on the teeth of the pinion or gear, a special flexible coupling (Fig. 5) is used. This coupling consists simply of two flanged collars, one on the turbine and one on the pinion drive shaft, and a ring *R* bolted to the part of the coupling on the turbine shaft. There is a slight clearance between the ring *R* and the hub *S*, and the driving force is transmitted through the ring to the hub by means of steel balls *B* inserted in holes drilled partly in the ring and partly in the hub. A retaining ring *T* prevents the balls from coming out.

REDUCTION GEAR.

Although the principle of the Melville-Macalpin gear and its later development by George Westinghouse have been mentioned in these columns, a brief review may be in order at this time. Referring to Fig. 8, *AA* is a double-helical pinion, *BB* the driven gear and *CC* the frame carrying the pinion-shaft bearings; *DDD* are three pistons resting on suitable supports. Oil under pressure is introduced through the passage communicating with each of the pistons and causes the pinion frame *C* to float. Inasmuch as the three supporting cylinders are in communication with one another, the pinion frame is free to align itself in such a way as to bring about an even distribution of tooth pressure across the entire working face of the gear. To provide for reversed rotation, and, consequently a reversed thrust on the pinion frame, a second set of cylinders and pistons is placed on the opposite side, as may be seen in Fig. 9, which represents a cross-section through the floating pinion frame at the middle bearing. Low-pressure oil is introduced into the upper end of the central passage and through *J*, which communicates with the three shaft bearings. Assuming that the pinion is rotating in a clockwise direction, the reaction between it and the gear will cause the floating frame *L* to tilt slightly to the right, which brings the outlet to passage *F'* against the sleeve valve *K'* and seals the former. The spring in the valve *K'* provides easy contact and does away with any hammering.

Each bearing will draw oil from *J* and discharge through the opening on the right, past a ball check valve into the chamber *H'H'*, thence into the cylinders containing the supporting pistons *D'*. Since the outlet from *F'* is sealed by the valve *K'*, the oil pressure will build up, due to the

pumping action of the shaft, until it just balances the side thrust of the floating frame. The instant this pressure is exceeded, the pinion frame is forced slightly to the left, causing the upper end of *F'* to become unsealed and allowing the surplus oil to escape into the gear case from whence it is returned to passage *G*. In this way the valve *K'* throttles the discharge from *F'* sufficiently to maintain the pressure constant behind the pistons *D'*. With the reverse direction of rotation the action is the same, the valve *K* and passage *F* coming into use.

The pressure of the oil is proportioned to the force exerted at the pitch line of the gears. This force multiplied by the pitch-line speed in feet per minute divided by 33,000 gives the horsepower that is being transmitted. Therefore, by connecting a continuous-speed recorder and a recording pressure gage, a continuous dynamometer record may be had.

BRIDGE CONTROL.

A novel feature of the *Neptune's* equipment is the bridge-control mechanism which places the propelling machinery directly under the control of the navigating officer and does away with the necessity of using the engine-room telegraph. A change can be made to the telegraph and engine-room control in a few seconds if necessary. In the preliminary trials this control was found to give entire satisfaction. Fig. 10 shows the port turbine of the *Neptune* with the oil relays, the governor being on the other end; and Fig. 11 the bridge-control stand, which is so arranged that both turbines may be controlled independently or together.

AUXILIARIES.

The full line of marine auxiliaries comprises generating sets, both direct and alternating current; condensing equipment, including surface condensers, air pumps, condensate pumps and circulating pumps; high- and low-pressure centrifugal pumps and centrifugal fans. The principal characteristic of these is the use of a simple rotating element instead of many reciprocating parts.

GENERATING SETS.

Direct-current generating sets with direct drive are built in sizes of from 1 to 150 kw., and with gear drive in sizes of from 50 to 500 kw., the problem of drive in the larger units being in many respects similar to that of driving a propeller. These units are furnished either condensing or noncondensing up to 150 kw., and above this, condensing only. The weights of the geared sets range from 15 to 45 pounds per horsepower.

While direct current has heretofore been used almost exclusively in marine practice, several alternating-current installations have been made recently and its further use is anticipated. Owing to the desirability of high speeds with alternating-current generators, direct drive is employed exclusively with these sets. They are also condensing and are furnished in sizes of 100 to 500 kw., 60 cycles and voltages of 125, 220 and 440.

In the small generating sets the bearings are ring lubricated, but in the 25-kw. size and above, forced lubrication is employed.

CONDENSING EQUIPMENT.

The Westinghouse condensing plant, as shown in Fig. 17, consists of a surface condenser, a Leblanc air pump and a centrifugal circulating pump. These are furnished separately or combined on a shaft. Fig. 15 shows combined air, and circulating pumps with geared drive, and Fig. 16 combined air, condensate and circulating pumps with direct turbine drive.

The air pump is of the Leblanc type, which uses fresh water in a closed circuit, and is made in capacities from 800 to 25,000 square feet of cooling surface. For the benefit of those not familiar with this type of pump, its operation may be explained briefly as follows: Referring to Fig. 14, a continuous series of rapidly-moving layers of water are pro-

jected into the air chamber, condensing the vapor present and cooling and concentrating the air which is imprisoned between the pistons or vanes and carried out through the discharge nozzle, during which process it is compressed to atmospheric pressure. The water pistons have no clearances and there are no reverses; consequently no losses due to these causes.

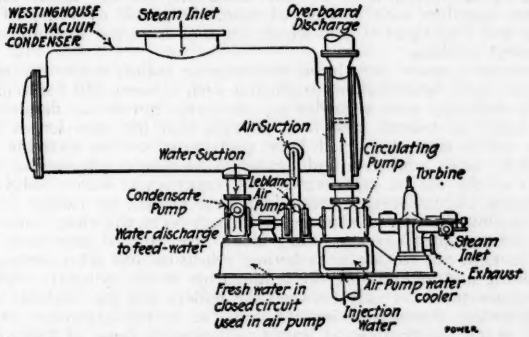


FIG. 17.—WESTINGHOUSE MARINE CONDENSING PLANT.

The condensate pump is a single-stage, double-inlet runner, horizontal type, although for naval use a special vertical type with single-inlet runner is supplied.

Either a single or double runner, double-inlet centrifugal pump is used for circulating, in capacities of from 400 to 40,000 gallons per minute against heads of from 15 to 60 feet, and at speeds of from 225 to 2,500 r.p.m. They weigh from 800 to 27,000 pounds complete.

In the type of turbine used for driving the auxiliaries there is a single-disk rotor with a single row of blades. In the noncondensing type the steam expands once and passes through the blades twice, whereas in the condensing type it expands twice and passes through the blades four times. By redirecting the steam through the same row of blades several times, its energy is fully utilized by a simple construction.—"Power."

A TORSION METER WITH VISIBLE SCALE.

By Dr. K. Suychiro, Professor of Naval Architecture at Tokio Imperial University. Paper read before the Institution of Naval Architects. Published in "Engineering," June 12, 1914. This describes the torsion meter devised by the author, which employs mirrors reflecting on a scale which is read through a telescope. Apparatus is illustrated.

BOILERS.

SUPERHEATED STEAM.

THE USE OF SUPERHEATERS AND SUPERHEATED STEAM IN MERCANTILE STEAMERS.

Paper read before the Institute of Naval Architects, April 2, 1914, by Harry Gray.

The reintroduction of superheaters in boilers, and the use of superheated steam in engines of the mercantile marine, has been brought about by

continuous research together with costly experiments by the greater knowledge obtained in the process of making and amalgamating metals, by the improvements in the manufacture of such metals into tubes and other suitable forms, by the introduction of oxy-acetylene and electric welding, by the preparation of lubricating oils for use under high temperatures, together with a mass of data, the result of years of experimenting and investigation, and which has now been put to the crucial test of practical working.

Superheaters, when introduced into marine boilers some 70 years ago, developed rapid deterioration, producing such a heavy bill for repairs and renewals that they were regarded as too costly, not to say dangerous, for use on board a steamer, and it is possible that the experiences and the troubles which then developed have contributed to the extreme caution exhibited by many engineers and steamship owners in considering the pros and cons of the use of superheaters and superheated steam today.

The steam engine being essentially a heat engine, no excuse is needed for advocating the use of superheat; if such were the case, however, the records of the past seventy years alone are full of instances of the devices brought out for steam jacketing, reheating and other arrangements for retaining and maintaining the temperature in the cylinders. The drop in the temperature, not only between the boilers and the engines, but also in the cylinders themselves, beyond that due to the expansion of steam, has been, if not the greatest, at least one important cause of loss of power in steam engines, as it has thereby increased the amount of saturation in the steam. Another loss arose from the amount of saturation brought over by the steam from the boilers, when priming was not violently taking place. This loss is seen more or less in all marine engines by the quantity of water which comes down through the piston-rod glands, to the detriment of the packing and the piston rods. It is also manifest by the noise which betrays the presence of water in the cylinders, although there may be none of the usual evidence of priming in the boilers, which shows that whilst a small percentage might be attributed to condensation in the cylinders, a large volume is really due to the heavy state of saturation of the steam coming from the boilers, and, moreover, that this is a variable quantity, due, no doubt, to the conditions of firing, circulation, or the quality of fuel.

WATER FROM CYLINDERS.

In order to obtain some data bearing upon this loss, measurements were taken of the water coming from the cylinders of quadruple-expansion engines of 3,000 indicated horsepower working under saturated-steam conditions, readings being taken during the voyage, and at times it was found that as much as 20 gallons per hour was drained off the M.P. 2 and L.P. steam chests. The fact that such a quantity of water was found to accumulate in the cylinders of a quadruple-expansion engine, working under saturated-steam conditions, convinced Alex. J. Dudgeon and the writer that superheat would convert this loss into effective horsepower and so contribute to a more economical result. The modern system of superheating steam passes the saturated steam from the boiler through small tubes placed in different positions, according to the type of boiler, whether water-tube or marine cylindrical multitubular, usually termed the "Scotch" boiler.

DESIGN OF SUPERHEATERS.

It is not proposed to deal with the various points of interest regarding the different types or design of superheaters which naturally arise, but which do not come within the scope of this paper, which is confined to the experience of the use of superheat on steamers, with special reference to the important question of economy and cost of upkeep, based on over three years' working in engines of both triple and quadruple-expansion type in the mercantile marine engaged in a regular trade, voyage after

voyage, to Australia via the Cape of Good Hope. In the system adopted (Schmidt's) the steam from the boilers passes into a vertical pipe, called the "saturated" header, placed in the smoke-box, from which small branch pipes are led horizontally across the front of the tube plates, the pipes passing down each tube of the row being doubled in a *U* form for that purpose so that each "element," as it is termed, is a series of *U's*, the other end being brought back to what is termed the "superheated" header. The jointing of each end of the element to the headers is effected by a small cross bar or "dog" with a stud through the center, so that each dog makes two joints. Careful supervision, testing and tightening up, as the pressure rises when getting up steam, prevents any leakages afterwards, as when once tight the fittings do not give trouble. A drain is fitted to both headers, that on the saturated header for blowing away any scum that might be brought over from the boiler, and which would possibly choke the lower rows of elements, and a drain on the superheated header to permit of a circulation of steam through the elements when getting up steam, or when the steam is not being circulated in consequence of the supply to the engines being shut off whilst working the engines to orders in ports. The elements are examined periodically, being removed from each nest of tubes in rotation, so many each voyage; thus all are dealt with at least once a year; but whenever the boilers are cleaned the ends of the elements are examined from the combustion chamber, as they are only about 9 inches inside from the back tube plates, for any signs of leakage at the weld of the *U* bend of the elements. These defects are something less than 0.1 per cent., and are generally only pin-holes. Even should it be necessary to deal with the *U* end it is not a serious matter, either in time or expense, and, in the event of a serious leak the steam from the boiler can be shut off the superheater and by-passed direct to the engines, whilst the defective element is withdrawn and the joints on the headers remade with blank plugs, the gross area through the elements allowing for a considerable reduction without unduly wire-drawing the superheated steam. Experience has shown no deterioration of the elements from corrosion or burning of the end, or any injurious action on the boiler tubes. The chief expense incurred with superheat is on account of extra labor when withdrawing these elements for inspection. None of the steamers under consideration has been delayed either in port or on the voyage from defects in superheater elements since being fitted, notwithstanding the fact that they are turned round quickly and have long runs, that of the *Port Augusta* being 45 days without a call at any port, and the *Port Lincoln* and *Port Macquarie* 39 days, with a call of a few hours only at Cape Town for coal and fresh water. The cleaning of the tubes on the voyage is effected by "Diamond Blowers" fitted in each combustion chamber, and they are blown through every day, the operation taking about two or three minutes for each nest, the soot which accumulates in the smoke box being cleared away through the doors provided for the purpose. These blowers can be fitted to double-ended as well as single-ended boilers.

INTERNAL LUBRICATION.

The absence of moisture, upon which marine engines rely for internal lubrication, makes the lubrication of the cylinders and valve faces of most vital importance when superheated steam is used. In the first instance, an excess of internal lubrication is advisable, until the pores of the metal surfaces become saturated and filled up with oil. When this has taken place it will be found that, although the surface of the cylinder walls may be cleaned and wiped when they are hot, upon the metal cooling down a film of oil will be squeezed out of the pores on to the surface of the metal. When this condition has been attained, the quantity of oil for internal lubrication may be reduced with safety.

On the *Port Augusta*, of 2,000 indicated horsepower, 1.5 gallons per day of cylinder oil were used at first for internal lubricating and swabbing of piston rods of both main and auxiliary engines; on the *Port Lincoln* and *Port Macquarie*, of 4,000 indicated horsepower, about 2 gallons per day, this being gradually reduced until now only 0.5 to 0.75 gallon is required. Another important detail with regard to this is that independent means of lubrication must be provided for each engine, either in the valve chest or cylinder. That for the high-pressure cylinder should be on the engine side of the stop and throttle valve, otherwise the surfaces are liable to become coated with an oil deposit during a long run, and may cause them to work stiff, thereby interfering with their steam tightness when brought into use again on working the engines to orders. It is advisable to arrange for independent lubrication for the low-pressure valve, as, owing to its being generally of the flat "D" type and unbalanced, the large surface even with a low pressure upon it, gives rise to considerable friction. It has been found in triple-expansion engines, where the medium-pressure cylinder is placed adjoining the high-pressure cylinder with short exhaust passages, that, after the surfaces become saturated with oil, the regular supply to the medium-pressure cylinder may be shut off, as it would appear that a sufficient quantity of the oil injected into the steam in the high-pressure valve chest becomes vaporized and is carried over to the medium-pressure valve chest with the exhaust. Nevertheless, in the first instance, a regular supply should be injected into the medium-pressure valve chest, and even when this is shut off, a little extra oil should be injected from time to time, according to the evidence of the running and condition of the surface when opened up for examination.

PROBLEM OF LUBRICATION.

The selection of a suitable lubricant for internal lubrication under the temperatures and conditions met with when using superheated steam is one requiring consideration. There are several oils on the market with a flash point under the open test of from 610 degrees to 630 degrees F., but due consideration must be given to their composition, whether it represents an absolute mineral oil or a compound of a mineral with an animal or vegetable oil, which, it is claimed, adds to the lubricating qualities without creating troubles from carbonization or other causes; this, however, is a doubtful point. Upon the question of the evaporation point, and also the flash point, when the oil is under pressure, we know of no reliable data; possibly these points are higher under pressure than those obtained by the tests under atmospheric conditions. It is absolutely necessary to have a reliable system of filtration for the feed water, so as to ensure the abstraction of the oil and to safeguard the boilers from the possibility of any traces getting through. The difficulties at first met with to obtain this result have been overcome by fitting a large gravitation filter.

FILTRATION.

The whole secret of filtration is "time" to allow the feed water to come almost to rest and enable the oil to rise to the surface and be collected; afterwards the feed water should pass through a chamber filled with coke, and finally through a section fitted with "cartridge" cylinders, covered with filter-cloth toweling of substantial body having a rough surface. The more compartments of the first or settling stage that are provided, the longer the coke and filter-cloth sections will last without requiring to be changed. The filter must be so placed that the water will gravitate to the same water level as the weir in the hot well of the air pumps. It is essential that the covers of this filter should be always open when working, so that it may be under observation, and that the thick

scum accumulating on the surface of the settling chambers may be removed by hand from time to time.

The cleaning of the coke and filter-cloth chambers can be done very quickly if a full set of spare parts is carried, which can be kept charged with fresh coke and with clean filter-cloths on, ready for use. When such spare parts are provided there is no necessity for a by-pass arrangement, as the working of the filter is not interfered with during the process of changing the filtering medium, and the time is so short that no danger from oil passing through with the feed water is experienced.

The feed water betrays not the slightest sign of oil, even in emulsion, when drawn off from the feed pumps; there is no "taste" of oil perceptible; the internal surfaces of the boilers, even on the water line, do not show any signs of oil, and this has been confirmed in each of the four boilers in both the steamers with quadruple-expansion engines having passenger certificates, upon inspection at the end of six and twelve months' service, as well as at the annual survey on the other steamer, fitted with triple-expansion engines and two boilers. The temperature of the steam during the various stages is ascertained by pyrometers fitted to the superheater steam pipe of each boiler to the H.P. and M.P. 1 steam chests, and by thermometers fitted in the steam chests of the M.P. 2 and L.P. engines. The general experience with the pyrometers having long connecting capillary tubes filled with ether or mercury, by means of which the temperature is recorded on the dial, shows a tendency to give unduly low readings after months of constant use, to the extent of about 5 per cent., necessitating their being frequently tested, and short connections are therefore recommended, although the position of the dials may not then be so conveniently arranged for observation. The variations in the reading of the pyrometers, due to the fluctuations of the temperature of the steam following on the condition of the fires, indicate beforehand the rise or fall of the steam pressure, and enable the engineer on watch to know in which boiler the furnace temperatures are falling, through the fires getting low or dirty, and so give the necessary orders to maintain a full steam pressure. The fitting of pyrometers and thermometers in this manner has given some very interesting information as to how far the superheat is carried through the engine, in other words, whether the temperature of the steam due to superheat falls more or less quickly than the temperature of the steam consequent upon the pressure, so as to indicate at what stage, if any, the steam loses all "superheat" and returns to the "saturated" state.

Steam chest.	S. S. *Port Augusta*. Triple-expansion engines.				S. S. *Port Lincoln* and *Port Macquarie*. Quadruple-expansion engines.			
	Gage pressure in steam chests.	Temperature due to steam pressure.	Temperature recorded.	Degree of superheat.	Gage pressure in steam chests.	Temperature due to steam pressure.	Temperature recorded.	Degree of superheat.
	Lbs.	Degs.F.	Degs.F.	Degs.F.	Lbs.	Degs.F.	Degs.F.	Degs.F.
High pressure.....	160	370	550	180	206	389	600	+211
First intermediate.....	53	300	400	100	97	335	460	+125
Second intermediate...	...	...	...	...	38	284	290	+ 6
Low pressure	10	240	?	?	9	237	220	— 17

The preceding table, which is approximately reliable, gives the average results obtained, although the higher temperature taken by the pyrometers may, as before mentioned, be lower than was actually the case.

It will be seen that superheat is shown in the steam chest of the first three engines, and almost in the low-pressure, while at times a few degrees of superheat are reported to have been actually registered there. The cut-offs are about: H.P., 73 per cent; M.P. 1, 70 per cent.; M.P. 2, 70 per cent.; L.P., 70 per cent.

The steamers from which these data were obtained belong to W. Milburn & Co., of London, and our thanks are due to Mr. Milburn for his permission to place the results before the institution. The *Port Augusta* was built and engined by Hawthorn, Leslie & Co., in 1906; the boilers were fitted with superheaters and the necessary alterations made to the engines, etc., by the North-Eastern Marine Engineering Co., Ltd., of Wallsend-on-Tyne, in May, 1911, when the boilers and engines were five years old. The *Port Lincoln* and *Port Macquarie* were built by Hawthorn, Leslie & Co., and engined by the North-Eastern Marine Engineering Co., Ltd., of Wallsend, in 1912. The boilers were designed for working the engines under saturated-steam requirements, but fitted with superheaters. The *Port Albany* was also built by Hawthorn, Leslie & Co., and engined by the North-Eastern Marine Engineering Co., but the boilers were designed for and fitted with superheaters.

In the case of the *Port Augusta* no alteration was made to the boilers, the grate surface or any of the saturated-steam connections, the only

Average of consecutive voyages.	S. S. *Port Augusta*. Triple expansion.		S. S. *Port Lincoln* and *Port Macquarie*. Quadruple expansion.
	With saturated steam.	With superheated steam.	With superheated steam.
Port Augusta, London to Adelaide, via the Cape	7	5	.....
Port Lincoln and *Port Macquarie*, London to Melbourne, calling at the Cape	.....	.....	6
Days on voyage	46 days, 10 hrs. 46 min.	49 days, 12 hrs., 2 mins.	41 days, 1 hr. 35 mins.
Days under steam	45 days, 17 hrs., 38 min.	46 days, 14 hrs., 1 min.	39 days, 2 hrs, 43 mins.
Boiler pressure, in pounds per square inch	180	180	220
Speed, in knots	10.67	10.46	12.7
Draught (mean) leaving London	24 ft., 9½ ins.	24 ft., 5½ ins.	24 ft., 10⅜ ins.
Displacement (mean) leaving London	10,150 tons.	10,000 tons.	12,266 tons.
Coal used for all purposes	1,744	1,560.45	2,335.05
Less deductions for raising steam, banked fires, winches, galley fires, crew's bogies, and condensing fresh water	34	15.0	61.88
Coals used for main boilers for supplying steam on voyage for main engines and auxiliaries, also steering gear and electric light	1,710	1,545.45	2,273.17
Less deduction for *Port Augusta* steering gear and electric light at 1 ton per day	46	49.5	.....
Less deduction for *Port Lincoln* and *Port Macquarie*, including also steam cooking process and boilers and provision refrigerator machine at 2 tons per day	.....	.....	81.9
Coals used for main engines and auxiliaries (circulating pump, feed pump, evaporator and fan)	1,664	1,495.95	2,191.27
Coal per day	36.65 tons.	32.1 tons.	56 tons.
Coal per indicated horsepower, in pounds per hour	1.6	1.4	1.29
Quality of coal as indicated by loss reported on voyage (ashes, etc.)	14 per cent.	13 per cent.	16.4 per cent.
Indicated horsepower	2,102	2,005.4	4,027

change or addition being in the case of pipes or connections coming in contact with the superheated steam, and some modification was made to the smoke boxes to allow of the superheater headers being fitted. The alterations to the engines consisted, in addition to the usual general overhaul, of fitting a balanced flat valve in place of the ordinary "D" valve for the M.P. engine, fitting of suitable piston-rod metallic packing, steel-neck bushes instead of brass, and additional lagging to cylinders, etc. A gravitation filter was installed, and afterwards enlarged and improved until its efficiency was satisfactory. The *Port Lincoln* and *Port Macquarie* are duplicate vessels in every respect; they have no auxiliary boiler, so

Particulars.	*Port Augusta.*	*Port Lincoln.*	*Port Macquarie.*	*Port Albany.*
Length	380 ft. 6 ins.	425 ft., 9 ins.	425 ft., 9 ins.	425 ft., 9 ins.
Breadth	49 feet, 1 in.	54 feet.	54 feet.	54 feet.
Depth, molded	28 ft., 7 ins.	31 ft., 10½ ins.	31 ft., 10½ ins.	31 ft., 10½ ins.
Gross tonnage	4,003	7,236	7,236	7,236
Dead weight	7,226	9,254	9,254	.....
Engines	Triple.	Quadruple.	Quadruple.	Quadruple
Cylinders	27, 45, 74 ins.	27½, 39, 56, 81½ inches.	27½, 39, 56, 81½ inches.	27½, 39, 56, 81½ inches.
Stroke	48 inches.	54 inches.	54 inches.	54 inches.
I.H.P. on voyage	2,100	4,100	4,100	4,100
Boilers, number	Two.	Four.	Four.	Four.
Boilers, type	Cylindrical, single ended.	Cylindrical, single ended.	Cylindrical, single ended.	Cylindrical, single ended.
Total heating surface	5,720	11,600	11,600	11,360
Total grate surface	137	240	240	260
Total superheat surface	2,390	4,000	4,000	4,320
Working pressure	180	220	220	220
External diam. of boiler tube, plain	2½ inches.	2¾ inches.	2¾ inches	3 inches.
External diam. of boiler tube, stay	2½ inches.	2¾ inches.	2¾ inches.	3 inches.
Internal diam. of superheater tubes	13 milimeters.	13 milimeters.	13 milimeters.	15 milimeters.
Forced draft	Howden.	Howden.	Howden.	Howden.

that all demands for steam are supplied by the main boilers, these are increased above the usual requirements of auxiliaries owing to the vessels being fitted up for emigrants, which necessitates additional galleys, pantries, refrigerator machine, and electric light. The *Port Albany* is a duplicate of the *Port Lincoln*, but fitted for carrying frozen cargo, and not fitted for emigrants. Before dealing with the tabulated results of the performances of the steamers under consideration some description of the data available, and the basis on which the deductions have been drawn, is essential for the purpose of arriving at their value, not only to engineers, but also to ship owners. Mercantile steamers are for the commercial purpose of carrying passengers and cargo at remunerative freights, and, to do so, the cost of running involves a heavy expenditure for fuel, either coal or oil; the ordinary means of ascertaining such expenditure on the fuel account is by calculating the tons of fuel used per day.

The data for this purpose are obtained from the voyage abstracts of the engineers' log book, which latter is also available for the verification of the daily averages as set forth in the abstract sheet. These data, when covering a number of consecutive voyages, assume a value, and in general practice are accepted as a fair basis of comparison, so that, with a known consumption of tons of coal per day, the quantity in bunkers required for a definite number of steaming days can be ascertained. The amount of coal required for loading and discharging cargo and other purposes is estimated separately according to the conditions and circumstances of the voyage.

The tabulated results are therefore not compiled upon data, such as are available in a laboratory, on the "test" table, or even on a "trial trip" with a special staff of engineers to collect them over a few hour , or per-

haps days, but they are the averages of months and years of every day's work, which for commercial purposes is the best guide, as representing what the shipowner has to pay for. The data available with the triple-expansion engines of the *Port Augusta* comprise seven consecutive voyages extending over three and a half years, using saturated steam, as well as the five following voyages, after being fitted with superheat, extending over three years, all of which are from London to Adelaide via the Cape of Good Hope, most of them being without any call at an intermediate port. The reason that the outward voyages have been taken is, not only that they cover the same run, but also because the same bunkers for the whole voyage were taken either on the Tyne or at Middlesbrough from the Auckland (Durham) or Mickley coal seams. The conditions, therefore, are exceptional, if not unique, for the purpose of comparison. The data dealt with of the quadruple-expansion engines of the steamers *Port Lincoln* and *Port Macquarie* are on exactly the same basis as that of the *Port Augusta,* and cover three voyages of each steamer to Melbourne from London, calling at the Cape, with this difference, that two-thirds of the bunkers for the voyage were Mickley coal (unscreened) and one-third Natal coal, which latter gives a higher percentage of loss (ashes, etc.), and consequent consumption, than the North Country coal. There is also a deduction of two tons instead of one ton a day on account of these steamers carrying more than 600 emigrants, besides a crew of 125, or about 740 souls all told, entailing a heavy expenditure of coal for galley fires, bakers' ovens, and steam for the cooking presses, boilers, pantry sinks, plate heaters, etc.

The above results cover all the contingencies which arise on a long sea voyage—weather, adverse trade winds, currents, also coal troubles arising from its being only "fair," or what is described as "dirty" or "small;" further, the human element is included, a most important factor affecting voyage results. Therefore these data have a special value to the shipowner.

The engineer naturally asks for a higher standard, by which to gage the capabilities and possibilities of the use of superheat; for this reason the results of a selected voyage, from London to Cape Town, of one of the steamers, fitted with quadruple engines is given when the coal was described as "good" but "small," the weather was "fair to good," and the stokehold crowd well up to the average. Then we get:

	Selected.	Average of 5 voyages.
Days on passage	19 days, 10 hours.	19 ds., 17 hrs., 28 minutes.
Speed	12.92 knots.	12.77 knots.
Coal consumption per day for main engines and auxiliaries	50.33 tons.	51 tons
Coal per I.H.P	1.043 tons.	1.15 tons.
I.H.P.	4,500	4,'22

The part of the voyage from the Cape to Australia is generally more detrimental to exhibition results, owing to weather conditions, as well as to the less satisfactory quality of Natal bunker coal taken at the Cape, which consequently increases the daily consumption without any increase of indicated horsepower. From the results obtained we get the following consumption:

	Lbs. per I.H.P. per hr.
Triple-expansion, saturated	1.6
Triple-expansion, superheated	1.4
Quadruple-expansion, saturated	1.34
Quadruple-expansion, superheated	1.15

The figures for quadruple engines with saturated steam are taken from similar data of two steamers fitted with engines of 3,000 indicated H.P. during seven voyages each to Australia via the Cape, with the same

bunkers as used for the superheated quadruple engines as far as the Cape already dealt with.

In the following comparison of the economy obtained the consumption for quadruple engines superheated is taken at 1.15 pounds per hour per indicated horsepower obtained on the voyage as far as the Cape, because coal from the same collieries—namely, Auckland or Mickley—was burnt

ECONOMY AND SAVING OF COAL IN TONS PER DAY PER 1,000 I.H.P.

	Lbs. per I.H.P. per hour.		Lbs. per I.H.P. per hour.	Economy, per cent.	Saving, tons per day per 1,000 I.H.P.
Triple expansion superheated at	1.4	Over triple expansion saturated at	1.6	12.14	2.14
Quadruple expansion saturated at	1.34	Over triple expansion saturated at	1.6	16.25	2.79
Quadruple expansion superheated at	1.15	Over triple expansion saturated at	1.6	28.1	4.82
Quadruple expansion superheated at	1.15	Over triple expansion superheated at	1.4	17.85	2.68
Quadruple expansion superheated at	1.15	Over quadruple expansion saturated at	1.34	14.2	2.03

as was used on the other steamers. In the case of the voyage averages of the *Port Lincoln* and *Port Macquarie*, the consumption works out at 1.29 pounds per hour per indicated horsepower in consequence of one-third of the coal being from Natal, giving a higher percentage of loss.

These results are shown on the diagram up to 10,000 indicated horsepower.

The additional cost of fitting superheat cannot be set down at any definite figure, as, although a large number of installations have been fitted, the different conditions that have to be complied with make a comparison, in order to form a standard of price, very conflicting; still, for rough estimating, it may be taken as ranging from 15s to 20s per indicated horsepower, against which the reduced size and consequent cost of the boilers must be considered.

The full benefit of superheat can only be obtained by extending its use to all the auxiliaries, and this has been carried out on the vessels fitted when new. The steam pipes are of steel and the gland packings mostly metallic. The temperature used is about 500 degrees F., and is regulated by a mixing valve from the saturated-steam pipe line. This arrangement ensures dry steam to the auxiliaries without any injury, although they are not all specially constructed for the use of superheated steam. Most of the leading makers of auxiliary engines make the necessary alteration for moderate superheat with but little, if any, extra charge. The mixing of superheated steam with the saturated supply for the winches is also a great advantage, even though very little superheat, if any, gets so far.

The use of superheat on turbines is another and most interesting phase of the subject, and one on which a resumé of experience would be most valuable whether on the turbine direct or after passing through the reciprocating engine.

The data on the use of superheated steam during the last three years contained in this paper has been collected by the writer's firm in their professional capacity of consulting engineers to the owners of the steamers. The fact that superheat has been fitted in all their subsequent vessels built, after a careful comparison as judged from the owners' standard of coals paid for, prompted the writer to place this information before the members of the Institution as pointing to the facts:

1. The economy of coal claimed is maintained.
2. The economy with triple-expansion engines of 2,000 indicated H.P. after being altered to use superheat has been 12.14 per cent.
3. The economy with quadruple-expansion engines fitted with superheat over triple-expansion similarly fitted is about 17.85 per cent.

4. The wear on the machinery is not appreciably increased where proper lubrication of internal surfaces is maintained.

5. The filtration of oil from the feed water has been successfully carried out, so as to ensure its satisfactory condition.

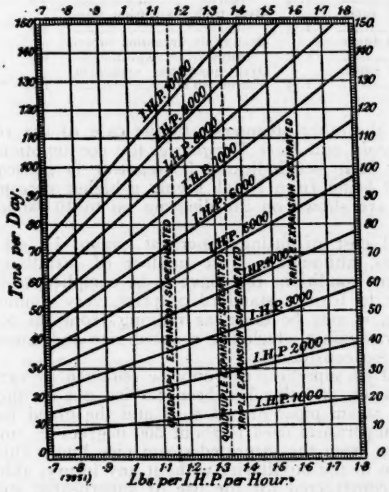
6. No danger from oil getting into the boiler need be feared with a filter such as was used.

7. The arrangement and fitting of the superheater elements and pipe connections present no serious objections.

8. The maintenance of the superheater elements in an efficient condition requires only ordinary attention.

9. In using superheat there is no necessity to carry any additional spare gear.

10. There is no necessity to carry any spare superheater elements



11. The first cost has been recovered in one year on the basis that the vessel is under steam for 200 days, as a result, not only of the saving of bunker coal, but also of the additional freight carried in lieu of the weight saved thereby. In subsequent years the whole gain is for the profit of the shipowner, subject to, say, 5 per cent. of same for additional overhaul and maintenance of the superheater elements, etc., and the usual allowances for insurance and depreciation on first into the engineers in charge, and to see that the working instructions are implicitly carried out.

The number of steamers fitted with superheaters during recent years is an indication of successful working under superheat conditions. The following figures though far from being a complete record, are worthy of note and consideration:

	No. of steamers.	Total I.H.P.
Hide superheaters	20	...
Yarrow superheaters	13	261,000
Babcock & Wilcox superheaters	29	316,675
Thornycroft superheaters	...	60,000
Schmidt superheaters	1,042	1,322,092

—"The Marine Review."

EQUIVALENT EVAPORATION FROM

Temperature of Feed Water Degrees Fahrenheit	Pressure of Steam in Pounds Absolute—Dry Saturated												
	15	25	35	45	55	65	75	85	95	105	115	125	135
32	1.1858	1.1958	1.2024	1.2073	1.2113	1.2144	1.2171	1.2195	1.2216	1.2234	1.2251	1.2266	1.2279
35	1.1827	1.1927	1.1993	1.2042	1.2081	1.2113	1.2140	1.2164	1.2184	1.2203	1.2219	1.2235	1.2248
40	1.1775	1.1875	1.1941	1.1990	1.2030	1.2062	1.2088	1.2112	1.2133	1.2151	1.2168	1.2183	1.2197
45	1.1723	1.1823	1.1889	1.1939	1.1978	1.2010	1.2037	1.2060	1.2081	1.2099	1.2116	1.2131	1.2145
50	1.1672	1.1772	1.1838	1.1887	1.1926	1.1958	1.1985	1.2009	1.2029	1.2048	1.2064	1.2080	1.2093
55	1.1620	1.1720	1.1786	1.1836	1.1875	1.1907	1.1933	1.1957	1.1978	1.1996	1.2013	1.2028	1.2042
60	1.1569	1.1669	1.1735	1.1784	1.1823	1.1855	1.1882	1.1906	1.1926	1.1945	1.1961	1.1977	1.1990
65	1.1517	1.1617	1.1683	1.1733	1.1772	1.1804	1.1830	1.1854	1.1875	1.1893	1.1910	1.1925	1.1939
70	1.1466	1.1566	1.1632	1.1681	1.1720	1.1752	1.1779	1.1803	1.1823	1.1842	1.1858	1.1874	1.1887
75	1.1414	1.1514	1.1580	1.1630	1.1669	1.1701	1.1728	1.1751	1.1772	1.1790	1.1807	1.1823	1.1836
80	1.1363	1.1463	1.1529	1.1578	1.1618	1.1650	1.1676	1.1700	1.1721	1.1739	1.1756	1.1771	1.1785
85	1.1312	1.1412	1.1478	1.1527	1.1566	1.1598	1.1625	1.1649	1.1669	1.1688	1.1704	1.1720	1.1733
90	1.1260	1.1360	1.1426	1.1476	1.1515	1.1547	1.1574	1.1597	1.1618	1.1636	1.1653	1.1668	1.1682
95	1.1209	1.1309	1.1375	1.1424	1.1463	1.1495	1.1522	1.1546	1.1566	1.1585	1.1602	1.1617	1.1630
100	1.1158	1.1258	1.1323	1.1373	1.1412	1.1444	1.1471	1.1495	1.1515	1.1534	1.1550	1.1566	1.1579
105	1.1106	1.1206	1.1272	1.1322	1.1361	1.1393	1.1420	1.1443	1.1464	1.1482	1.1499	1.1516	1.1528
110	1.1055	1.1155	1.1221	1.1270	1.1309	1.1341	1.1368	1.1392	1.1412	1.1431	1.1447	1.1463	1.1476
115	1.1004	1.1103	1.1169	1.1219	1.1258	1.1290	1.1248	1.1341	1.1361	1.1380	1.1396	1.1412	1.1425
120	1.0952	1.1052	1.1118	1.1167	1.1207	1.1239	1.1265	1.1289	1.1310	1.1328	1.1345	1.1360	1.1374
125	1.0901	1.1001	1.1067	1.1116	1.1155	1.1187	1.1214	1.1238	1.1258	1.1277	1.1293	1.1309	1.1322
130	1.0849	1.0949	1.1015	1.1065	1.1104	1.1136	1.1163	1.1186	1.1207	1.1225	1.1242	1.1257	1.1271
135	1.0798	1.0898	1.0964	1.1013	1.1052	1.1084	1.1111	1.1135	1.1155	1.1174	1.1190	1.1206	1.1219
140	1.0746	1.0846	1.0912	1.0962	1.1001	1.1033	1.1060	1.1083	1.1104	1.1123	1.1139	1.1154	1.1168
145	1.0695	1.0795	1.0861	1.0910	1.0950	1.0981	1.1008	1.1032	1.1053	1.1071	1.1088	1.1103	1.1116
150	1.0643	1.0743	1.0809	1.0859	1.0898	1.0930	1.0957	1.0981	1.1001	1.1020	1.1036	1.1052	1.1065
155	1.0592	1.0692	1.0758	1.0807	1.0846	1.0878	1.0905	1.0929	1.0950	1.0968	1.0985	1.1000	1.1013
160	1.0540	1.0640	1.0706	1.0756	1.0795	1.0827	1.0854	1.0877	1.0898	1.0917	1.0933	1.0948	1.0962
165	1.0489	1.0589	1.0655	1.0704	1.0743	1.0775	1.0802	1.0826	1.0846	1.0865	1.0881	1.0897	1.0910
170	1.0437	1.0537	1.0603	1.0653	1.0692	1.0724	1.0751	1.0774	1.0795	1.0813	1.0830	1.0845	1.0859
171	1.0427	1.0527	1.0593	1.0642	1.0681	1.0713	1.0740	1.0764	1.0785	1.0803	1.0820	1.0835	1.0848
172	1.0417	1.0517	1.0583	1.0632	1.0671	1.0703	1.0730	1.0754	1.0774	1.0793	1.0809	1.0825	1.0838
173	1.0406	1.0506	1.0572	1.0622	1.0661	1.0693	1.0720	1.0743	1.0764	1.0782	1.0799	1.0814	1.0828
174	1.0396	1.0496	1.0562	1.0611	1.0651	1.0683	1.0709	1.0733	1.0754	1.0772	1.0789	1.0804	1.0817
175	1.0386	1.0486	1.0552	1.0601	1.0640	1.0672	1.0699	1.0723	1.0743	1.0762	1.0778	1.0793	1.0807
176	1.0375	1.0475	1.0541	1.0591	1.0630	1.0662	1.0689	1.0712	1.0733	1.0752	1.0768	1.0783	1.0797
177	1.0365	1.0465	1.0531	1.0580	1.0620	1.0651	1.0678	1.0702	1.0723	1.0741	1.0758	1.0773	1.0786
178	1.0355	1.0455	1.0521	1.0570	1.0609	1.0641	1.0668	1.0692	1.0712	1.0731	1.0747	1.0763	1.0776
179	1.0344	1.0444	1.0510	1.0560	1.0599	1.0631	1.0658	1.0681	1.0702	1.0721	1.0737	1.0752	1.0766
180	1.0334	1.0434	1.0500	1.0549	1.0589	1.0621	1.0647	1.0671	1.0692	1.0710	1.0727	1.0742	1.0756
181	1.0324	1.0424	1.0490	1.0539	1.0578	1.0610	1.0637	1.0661	1.0681	1.0700	1.0716	1.0732	1.0745
182	1.0313	1.0413	1.0479	1.0529	1.0568	1.0600	1.0627	1.0650	1.0671	1.0690	1.0706	1.0721	1.0735
183	1.0303	1.0403	1.0469	1.0518	1.0558	1.0590	1.0616	1.0640	1.0661	1.0679	1.0696	1.0711	1.0725
184	1.0293	1.0393	1.0459	1.0508	1.0547	1.0579	1.0606	1.0630	1.0650	1.0669	1.0685	1.0701	1.0714
185	1.0282	1.0382	1.0448	1.0498	1.0537	1.0569	1.0596	1.0619	1.0640	1.0659	1.0675	1.0691	1.0704
186	1.0272	1.0372	1.0438	1.0488	1.0527	1.0559	1.0585	1.0609	1.0630	1.0648	1.0665	1.0680	1.0694
187	1.0262	1.0362	1.0428	1.0477	1.0516	1.0548	1.0575	1.0599	1.0619	1.0638	1.0654	1.0670	1.0683
188	1.0251	1.0351	1.0417	1.0467	1.0506	1.0538	1.0565	1.0588	1.0609	1.0628	1.0644	1.0660	1.0673
189	1.0241	1.0341	1.0407	1.0457	1.0496	1.0528	1.0554	1.0578	1.0599	1.0617	1.0634	1.0649	1.0663
190	1.0231	1.0331	1.0397	1.0446	1.0485	1.0517	1.0544	1.0568	1.0588	1.0607	1.0623	1.0639	1.0652
191	1.0220	1.0320	1.0386	1.0436	1.0475	1.0507	1.0534	1.0557	1.0578	1.0597	1.0613	1.0629	1.0642
192	1.0210	1.0310	1.0376	1.0425	1.0465	1.0497	1.0523	1.0547	1.0568	1.0586	1.0603	1.0618	1.0632
193	1.0200	1.0300	1.0366	1.0415	1.0454	1.0486	1.0513	1.0537	1.0557	1.0576	1.0592	1.0608	1.0621
194	1.0189	1.0289	1.0355	1.0405	1.0444	1.0476	1.0503	1.0526	1.0547	1.0566	1.0582	1.0597	1.0611
195	1.0179	1.0279	1.0345	1.0394	1.0434	1.0466	1.0492	1.0516	1.0537	1.0555	1.0572	1.0587	1.0601
196	1.0169	1.0269	1.0335	1.0384	1.0423	1.0455	1.0482	1.0506	1.0526	1.0545	1.0561	1.0577	1.0590
197	1.0158	1.0258	1.0324	1.0374	1.0413	1.0445	1.0472	1.0495	1.0516	1.0535	1.0551	1.0566	1.0580
198	1.0148	1.0248	1.0314	1.0363	1.0403	1.0435	1.0461	1.0485	1.0506	1.0524	1.0541	1.0556	1.0570
199	1.0138	1.0238	1.0304	1.0353	1.0392	1.0424	1.0451	1.0475	1.0495	1.0514	1.0530	1.0546	1.0559
200	1.0127	1.0227	1.0293	1.0343	1.0382	1.0414	1.0441	1.0464	1.0485	1.0504	1.0520	1.0535	1.0549
201	1.0117	1.0217	1.0283	1.0332	1.0372	1.0404	1.0430	1.0454	1.0475	1.0493	1.0510	1.0525	1.0539
202	1.0107	1.0207	1.0273	1.0322	1.0361	1.0393	1.0420	1.0444	1.0464	1.0483	1.0499	1.0515	1.0528
203	1.0096	1.0196	1.0262	1.0312	1.0351	1.0383	1.0410	1.0433	1.0454	1.0472	1.0489	1.0504	1.0518
204	1.0086	1.0186	1.0252	1.0301	1.0340	1.0372	1.0399	1.0423	1.0444	1.0462	1.0479	1.0494	1.0507
205	1.0076	1.0176	1.0242	1.0291	1.0330	1.0362	1.0389	1.0413	1.0433	1.0452	1.0468	1.0484	1.0497
206	1.0065	1.0165	1.0231	1.0281	1.0320	1.0352	1.0379	1.0402	1.0423	1.0441	1.0458	1.0473	1.0487
207	1.0055	1.0155	1.0221	1.0270	1.0309	1.0341	1.0368	1.0392	1.0413	1.0431	1.0448	1.0463	1.0476
208	1.0045	1.0144	1.0210	1.0260	1.0299	1.0331	1.0358	1.0381	1.0402	1.0421	1.0437	1.0453	1.0466
209	1.0034	1.0134	1.0200	1.0250	1.0289	1.0321	1.0347	1.0371	1.0392	1.0410	1.0427	1.0442	1.0456
210	1.0024	1.0124	1.0190	1.0239	1.0278	1.0310	1.0337	1.0361	1.0381	1.0400	1.0416	1.0432	1.0445
212	1.0003	1.0103	1.0169	1.0218	1.0258	1.0290	1.0316	1.0340	1.0361	1.0379	1.0396	1.0411	1.0425
215	0.9972	1.0072	1.0138	1.0188	1.0227	1.0259	1.0285	1.0309	1.0330	1.0348	1.0365	1.0380	1.0394
220	0.9920	1.0020	1.0086	1.0135	1.0174	1.0206	1.0233	1.0257	1.0277	1.0296	1.0312	1.0328	1.0341
225	0.9868	0.9968	1.0034	1.0083	1.0123	1.0155	1.0181	1.0205	1.0226	1.0244	1.0261	1.0276	1.0290
230	0.9816	0.9916	0.9981	1.0031	1.0070	1.0102	1.0129	1.0153	1.0173	1.0192	1.0208	1.0224	1.0237
235	0.9764	0.9864	0.9930	0.9979	1.0019	1.0050	1.0077	1.0101	1.0122	1.0140	1.0157	1.0172	1.0185
240	0.9711	0.9811	0.9877	0.9927	0.9966	0.9998	1.0025	1.0048	1.0069	1.0088	1.0104	1.0120	1.0133
245	0.9660	0.9759	0.9825	0.9874	0.9913	0.9945	0.9972	0.9996	1.0016	1.0035	1.0052	1.0067	1.0080
250	0.9606	0.9706	0.9772	0.9822	0.9861	0.9893	0.9920	0.9943	0.9964	0.9982	0.9999	1.0014	1.0028
255	0.9555	0.9655	0.9721	0.9770	0.9809	0.9841	0.9868	0.9892	0.9912	0.9931	0.9947	0.9963	0.9976
260	0.9502	0.9602	0.9668	0.9718	0.9757	0.9789	0.9816	0.9839	0.9860	0.9878	0.9895	0.9910	0.9924
265	0.9450	0.9550	0.9616	0.9665	0.9704	0.9736	0.9763	0.9787	0.9807	0.9826	0.9842	0.9858	0.9871
270	0.9397	0.9497	0.9563	0.9613	0.9652	0.9684	0.9710	0.9734	0.9755	0.9773	0.9790	0.9805	0.9819
275	0.9345	0.9446	0.9511	0.9560	0.9599	0.9631	0.9658	0.9682	0.9702	0.9721	0.9737	0.9754	0.9766
280	0.9292	0.9392	0.9458	0.9507	0.9547	0.9579	0.9605	0.9629	0.9650	0.9668	0.9685	0.9700	0.9714
285	0.9238	0.9338	0.9404	0.9454	0.9493	0.9525	0.9552	0.9575	0.9596	0.9615	0.9631	0.9647	0.9660
290	0.9186	0.9286	0.9352	0.9401	0.9440	0.9472	0.9499	0.9523	0.9543	0.9562	0.9579	0.9594	0.9607
295	0.9133	0.9233	0.9299	0.9349	0.9388	0.9420	0.9447	0.9470	0.9491	0.9509	0.9526	0.9541	0.9555
300	0.9080	0.9180	0.9246	0.9295	0.9334	0.9366	0.9393	0.9417	0.9437	0.9456	0.9472	0.9488	0.9501

N FROM AND AT 212 DEGREES.

	Pressure of Steam in Pounds Absolute—Dry Saturated												Temperature of Feed Water Degrees Fahrenheit
	135	145	155	165	175	185	195	205	215	225	235	245	
66	1.2279	1.2292	1.2304	1.2315	1.2324	1.2333	1.2342	1.2351	1.2357	1.2365	1.2372	1.2378	32
35	1.2248	1.2261	1.2273	1.2283	1.2293	1.2302	1.2311	1.2319	1.2326	1.2334	1.2341	1.2347	35
83	1.2197	1.2209	1.2221	1.2232	1.2241	1.2250	1.2259	1.2268	1.2274	1.2282	1.2289	1.2295	40
31	1.2145	1.2157	1.2170	1.2180	1.2189	1.2198	1.2208	1.2216	1.2222	1.2230	1.2238	1.2244	45
80	1.2093	1.2106	1.2118	1.2128	1.2137	1.2147	1.2156	1.2164	1.2170	1.2179	1.2186	1.2192	50
28	1.2042	1.2054	1.2066	1.2077	1.2086	1.2095	1.2104	1.2113	1.2119	1.2127	1.2134	1.2141	55
77	1.1990	1.2002	1.2015	1.2025	1.2034	1.2044	1.2053	1.2061	1.2067	1.2076	1.2083	1.2089	60
25	1.1939	1.1951	1.1963	1.1974	1.1983	1.1992	1.2002	1.2010	1.2016	1.2024	1.2031	1.2038	65
74	1.1887	1.1900	1.1912	1.1922	1.1932	1.1941	1.1950	1.1958	1.1965	1.1973	1.1980	1.1986	70
23	1.1836	1.1848	1.1861	1.1871	1.1880	1.1889	1.1899	1.1907	1.1913	1.1921	1.1929	1.1935	75
71	1.1785	1.1797	1.1809	1.1820	1.1829	1.1838	1.1847	1.1856	1.1862	1.1870	1.1877	1.1883	80
20	1.1733	1.1745	1.1758	1.1768	1.1777	1.1787	1.1796	1.1804	1.1810	1.1819	1.1826	1.1832	85
68	1.1682	1.1694	1.1707	1.1717	1.1726	1.1735	1.1745	1.1753	1.1759	1.1767	1.1775	1.1781	90
17	1.1630	1.1643	1.1655	1.1665	1.1675	1.1684	1.1693	1.1701	1.1708	1.1716	1.1723	1.1729	95
66	1.1579	1.1591	1.1604	1.1614	1.1623	1.1633	1.1642	1.1650	1.1657	1.1665	1.1672	1.1678	100
16	1.1528	1.1540	1.1552	1.1563	1.1572	1.1581	1.1591	1.1599	1.1606	1.1613	1.1620	1.1627	105
63	1.1476	1.1489	1.1501	1.1511	1.1521	1.1530	1.1539	1.1547	1.1553	1.1562	1.1569	1.1575	110
12	1.1425	1.1437	1.1450	1.1460	1.1469	1.1479	1.1488	1.1496	1.1503	1.1511	1.1518	1.1524	115
60	1.1374	1.1386	1.1398	1.1409	1.1418	1.1427	1.1436	1.1445	1.1452	1.1459	1.1466	1.1472	120
09	1.1322	1.1335	1.1347	1.1357	1.1366	1.1376	1.1385	1.1393	1.1400	1.1408	1.1415	1.1421	125
57	1.1271	1.1283	1.1295	1.1306	1.1315	1.1324	1.1334	1.1342	1.1349	1.1356	1.1363	1.1370	130
06	1.1219	1.1232	1.1244	1.1254	1.1264	1.1273	1.1282	1.1290	1.1298	1.1305	1.1312	1.1318	135
54	1.1168	1.1180	1.1193	1.1203	1.1212	1.1221	1.1231	1.1239	1.1246	1.1253	1.1261	1.1267	140
03	1.1116	1.1129	1.1141	1.1151	1.1161	1.1170	1.1179	1.1188	1.1195	1.1202	1.1209	1.1215	145
52	1.1065	1.1077	1.1090	1.1100	1.1109	1.1119	1.1128	1.1136	1.1143	1.1150	1.1158	1.1164	150
00	1.1013	1.1026	1.1038	1.1048	1.1058	1.1067	1.1076	1.1085	1.1092	1.1099	1.1106	1.1112	155
48	1.0962	1.0974	1.0987	1.0997	1.1006	1.1015	1.1025	1.1033	1.1040	1.1047	1.1055	1.1061	160
97	1.0910	1.0923	1.0935	1.0945	1.0955	1.0964	1.0973	1.0981	1.0989	1.0996	1.1003	1.1009	165
45	1.0859	1.0871	1.0883	1.0894	1.0903	1.0912	1.0922	1.0930	1.0937	1.0944	1.0951	1.0958	170
35.	1.0848	1.0861	1.0873	1.0883	1.0893	1.0902	1.0911	1.0920	1.0927	1.0934	1.0941	1.0947	171
25	1.0838	1.0850	1.0863	1.0873	1.0882	1.0892	1.0901	1.0909	1.0916	1.0924	1.0931	1.0937	172
14	1.0828	1.0840	1.0853	1.0863	1.0872	1.0881	1.0891	1.0899	1.0906	1.0913	1.0921	1.0927	173
04	1.0817	1.0830	1.0842	1.0853	1.0862	1.0871	1.0880	1.0889	1.0896	1.0903	1.0910	1.0916	174
93	1.0807	1.0820	1.0832	1.0842	1.0852	1.0861	1.0870	1.0878	1.0886	1.0893	1.0900	1.0906	175
83	1.0797	1.0809	1.0822	1.0832	1.0841	1.0850	1.0860	1.0868	1.0875	1.0882	1.0890	1.0896	176
73	1.0786	1.0799	1.0811	1.0822	1.0831	1.0840	1.0849	1.0858	1.0865	1.0872	1.0879	1.0885	177
63	1.0776	1.0789	1.0801	1.0811	1.0820	1.0830	1.0839	1.0847	1.0854	1.0862	1.0869	1.0875	178
52	1.0766	1.0778	1.0791	1.0801	1.0810	1.0819	1.0829	1.0837	1.0844	1.0851	1.0859	1.0865	179
42	1.0756	1.0768	1.0780	1.0791	1.0800	1.0809	1.0818	1.0827	1.0834	1.0841	1.0848	1.0854	180
32	1.0745	1.0758	1.0770	1.0780	1.0790	1.0799	1.0808	1.0816	1.0824	1.0831	1.0838	1.0844	181
21	1.0735	1.0747	1.0760	1.0770	1.0779	1.0788	1.0798	1.0806	1.0813	1.0820	1.0828	1.0834	182
11	1.0725	1.0737	1.0749	1.0760	1.0769	1.0778	1.0787	1.0796	1.0803	1.0810	1.0817	1.0823	183
01	1.0714	1.0727	1.0739	1.0749	1.0759	1.0768	1.0777	1.0785	1.0793	1.0800	1.0807	1.0813	184
91	1.0704	1.0716	1.0729	1.0739	1.0748	1.0758	1.0767	1.0775	1.0782	1.0789	1.0797	1.0803	185
80	1.0694	1.0706	1.0718	1.0729	1.0738	1.0747	1.0756	1.0765	1.0772	1.0779	1.0786	1.0793	186
70	1.0683	1.0696	1.0708	1.0718	1.0728	1.0737	1.0746	1.0754	1.0762	1.0769	1.0776	1.0782	187
60	1.0673	1.0685	1.0698	1.0708	1.0717	1.0727	1.0736	1.0744	1.0751	1.0758	1.0766	1.0772	188
49	1.0663	1.0675	1.0687	1.0698	1.0707	1.0716	1.0725	1.0734	1.0741	1.0748	1.0755	1.0762	189
39	1.0652	1.0665	1.0677	1.0687	1.0697	1.0706	1.0715	1.0723	1.0731	1.0738	1.0745	1.0751	190
29	1.0642	1.0654	1.0667	1.0677	1.0686	1.0695	1.0705	1.0713	1.0720	1.0727	1.0735	1.0741	191
18	1.0632	1.0644	1.0656	1.0667	1.0676	1.0685	1.0694	1.0703	1.0710	1.0717	1.0724	1.0731	192
08	1.0621	1.0634	1.0646	1.0656	1.0666	1.0675	1.0684	1.0692	1.0700	1.0707	1.0714	1.0720	193
97	1.0611	1.0623	1.0636	1.0646	1.0655	1.0664	1.0674	1.0682	1.0689	1.0696	1.0704	1.0710	194
87	1.0601	1.0613	1.0625	1.0636	1.0645	1.0654	1.0663	1.0672	1.0679	1.0686	1.0693	1.0700	195
77	1.0590	1.0603	1.0615	1.0625	1.0635	1.0644	1.0653	1.0661	1.0669	1.0676	1.0683	1.0689	196
66	1.0580	1.0592	1.0605	1.0615	1.0624	1.0633	1.0643	1.0651	1.0658	1.0665	1.0673	1.0679	197
56	1.0570	1.0582	1.0594	1.0605	1.0614	1.0623	1.0632	1.0641	1.0648	1.0655	1.0662	1.0668	198
46	1.0559	1.0572	1.0584	1.0594	1.0603	1.0613	1.0622	1.0630	1.0637	1.0645	1.0652	1.0658	199
35	1.0549	1.0561	1.0574	1.0584	1.0593	1.0602	1.0612	1.0620	1.0627	1.0634	1.0642	1.0648	200
25	1.0539	1.0551	1.0563	1.0574	1.0584	1.0592	1.0601	1.0610	1.0617	1.0624	1.0631	1.0637	201
15	1.0528	1.0541	1.0553	1.0563	1.0572	1.0582	1.0591	1.0599	1.0606	1.0614	1.0621	1.0627	202
04	1.0518	1.0530	1.0543	1.0553	1.0562	1.0571	1.0581	1.0589	1.0596	1.0603	1.0611	1.0617	203
94	1.0507	1.0520	1.0532	1.0542	1.0552	1.0561	1.0570	1.0579	1.0586	1.0593	1.0600	1.0606	204
84	1.0497	1.0509	1.0522	1.0532	1.0541	1.0551	1.0560	1.0568	1.0575	1.0583	1.0590	1.0596	205
73	1.0487	1.0499	1.0511	1.0522	1.0531	1.0540	1.0550	1.0558	1.0565	1.0572	1.0579	1.0586	206
63	1.0476	1.0489	1.0501	1.0511	1.0521	1.0530	1.0539	1.0548	1.0555	1.0562	1.0569	1.0575	207
53	1.0466	1.0478	1.0491	1.0501	1.0510	1.0520	1.0529	1.0537	1.0544	1.0552	1.0559	1.0565	208
42	1.0456	1.0468	1.0480	1.0491	1.0500	1.0509	1.0519	1.0527	1.0534	1.0541	1.0548	1.0555	209
32	1.0445	1.0458	1.0470	1.0480	1.0490	1.0499	1.0508	1.0516	1.0524	1.0531	1.0538	1.0544	210
11	1.0425	1.0437	1.0449	1.0460	1.0469	1.0478	1.0487	1.0496	1.0503	1.0510	1.0517	1.0523	212
80	1.0394	1.0406	1.0418	1.0429	1.0438	1.0447	1.0457	1.0465	1.0472	1.0479	1.0486	1.0493	215
28	1.0341	1.0353	1.0366	1.0376	1.0385	1.0395	1.0404	1.0412	1.0419	1.0427	1.0434	1.0440	220
76	1.0290	1.0302	1.0314	1.0325	1.0334	1.0343	1.0352	1.0361	1.0368	1.0375	1.0382	1.0388	225
24	1.0237	1.0249	1.0262	1.0272	1.0281	1.0291	1.0300	1.0308	1.0315	1.0323	1.0330	1.0336	230
72	1.0185	1.0198	1.0210	1.0221	1.0230	1.0239	1.0248	1.0257	1.0264	1.0271	1.0278	1.0284	235
20	1.0133	1.0145	1.0158	1.0168	1.0177	1.0187	1.0196	1.0204	1.0211	1.0218	1.0226	1.0232	240
67	1.0080	1.0093	1.0105	1.0115	1.0125	1.0134	1.0143	1.0151	1.0159	1.0166	1.0173	1.0179	245
14	1.0028	1.0040	1.0053	1.0063	1.0072	1.0081	1.0091	1.0099	1.0166	1.0113	1.0121	1.0127	250
63	0.9976	0.9989	1.0001	1.0011	1.0021	1.0030	1.0039	1.0047	1.0055	1.0062	1.0069	1.0075	255
10	0.9924	0.9936	0.9948	0.9959	0.9968	0.9977	0.9987	0.9995	1.0002	1.0009	1.0016	1.0023	260
58	0.9871	0.9884	0.9896	0.9906	0.9915	0.9925	0.9934	0.9942	0.9950	0.9957	0.9964	0.9970	265
05	0.9819	0.9831	0.9843	0.9854	0.9863	0.9872	0.9881	0.9890	0.9897	0.9904	0.9911	0.9918	270
54	0.9766	0.9778	0.9791	0.9801	0.9810	0.9820	0.9829	0.9837	0.9844	0.9852	0.9859	0.9865	275
00	0.9714	0.9726	0.9738	0.9749	0.9758	0.9767	0.9776	0.9785	0.9792	0.9799	0.9806	0.9812	280
47	0.9660	0.9672	0.9685	0.9695	0.9704	0.9714	0.9723	0.9731	0.9738	0.9745	0.9753	0.9759	285
94	0.9607	0.9620	0.9632	0.9642	0.9652	0.9661	0.9670	0.9678	0.9686	0.9693	0.9700	0.9706	290
41	0.9555	0.9567	0.9580	0.9590	0.9599	0.9608	0.9618	0.9626	0.9633	0.9640	0.9648	0.9654	295
88	0.9501	0.9514	0.9526	0.9536	0.9546	0.9555	0.9564	0.9572	0.9580	0.9587	0.9594	0.9600	300

Temperature of Feed Water Degrees Fahrenheit	Pressure of Steam in Pounds Absolute—Dry Saturated												
	15	25	35	45	55	65	75	85	95	105	115	125	135
32	1.1858	1.1958	1.2024	1.2073	1.2113	1.2144	1.2171	1.2195	1.2216	1.2234	1.2251	1.2266	1.2279
35	1.1827	1.1927	1.1993	1.2042	1.2081	1.2113	1.2140	1.2164	1.2184	1.2203	1.2219	1.2235	1.2248
40	1.1775	1.1875	1.1941	1.1990	1.2030	1.2062	1.2088	1.2112	1.2133	1.2151	1.2168	1.2183	1.2197
45	1.1723	1.1823	1.1889	1.1939	1.1978	1.2010	1.2037	1.2060	1.2081	1.2099	1.2116	1.2131	1.2145
50	1.1672	1.1772	1.1838	1.1887	1.1926	1.1958	1.1985	1.2009	1.2029	1.2048	1.2064	1.2080	1.2093
55	1.1620	1.1720	1.1786	1.1836	1.1875	1.1907	1.1933	1.1957	1.1978	1.1996	1.2013	1.2028	1.2042
60	1.1569	1.1669	1.1735	1.1784	1.1823	1.1855	1.1882	1.1906	1.1926	1.1945	1.1961	1.1977	1.1990
65	1.1517	1.1617	1.1683	1.1733	1.1772	1.1804	1.1830	1.1854	1.1875	1.1893	1.1910	1.1925	1.1939
70	1.1466	1.1566	1.1632	1.1681	1.1720	1.1752	1.1779	1.1803	1.1823	1.1842	1.1858	1.1874	1.1887
75	1.1414	1.1514	1.1580	1.1630	1.1669	1.1701	1.1728	1.1751	1.1772	1.1790	1.1807	1.1823	1.1836
80	1.1363	1.1463	1.1529	1.1578	1.1618	1.1650	1.1676	1.1700	1.1721	1.1739	1.1756	1.1771	1.1785
85	1.1312	1.1412	1.1478	1.1527	1.1566	1.1598	1.1625	1.1649	1.1669	1.1688	1.1704	1.1720	1.1733
90	1.1260	1.1360	1.1426	1.1476	1.1515	1.1547	1.1574	1.1597	1.1618	1.1636	1.1653	1.1668	1.1682
95	1.1209	1.1309	1.1375	1.1424	1.1463	1.1495	1.1522	1.1546	1.1566	1.1585	1.1602	1.1617	1.1630
100	1.1158	1.1258	1.1323	1.1373	1.1412	1.1444	1.1471	1.1495	1.1515	1.1534	1.1550	1.1566	1.1579
105	1.1106	1.1206	1.1272	1.1322	1.1361	1.1393	1.1420	1.1443	1.1464	1.1482	1.1499	1.1516	1.1528
110	1.1055	1.1155	1.1221	1.1270	1.1309	1.1341	1.1368	1.1392	1.1412	1.1431	1.1447	1.1463	1.1476
115	1.1004	1.1103	1.1169	1.1219	1.1258	1.1290	1.1248	1.1341	1.1361	1.1380	1.1396	1.1412	1.1425
120	1.0952	1.1052	1.1118	1.1167	1.1207	1.1239	1.1265	1.1289	1.1310	1.1328	1.1345	1.1360	1.1374
125	1.0901	1.1001	1.1067	1.1116	1.1155	1.1187	1.1214	1.1238	1.1258	1.1277	1.1293	1.1309	1.1322
130	1.0849	1.0949	1.1015	1.1065	1.1104	1.1136	1.1163	1.1186	1.1207	1.1225	1.1242	1.1257	1.1271
135	1.0798	1.0898	1.0964	1.1013	1.1052	1.1084	1.1111	1.1135	1.1155	1.1174	1.1190	1.1206	1.1219
140	1.0746	1.0846	1.0912	1.0962	1.1001	1.1033	1.1060	1.1083	1.1104	1.1123	1.1139	1.1154	1.1168
145	1.0695	1.0795	1.0861	1.0910	1.0950	1.0981	1.1008	1.1032	1.1053	1.1071	1.1088	1.1103	1.1116
150	1.0643	1.0743	1.0809	1.0859	1.0898	1.0930	1.0957	1.0981	1.1001	1.1020	1.1036	1.1052	1.1065
155	1.0592	1.0692	1.0758	1.0807	1.0846	1.0878	1.0905	1.0929	1.0950	1.0968	1.0985	1.1000	1.1013
160	1.0540	1.0640	1.0706	1.0756	1.0795	1.0827	1.0854	1.0877	1.0898	1.0917	1.0933	1.0948	1.0962
165	1.0489	1.0589	1.0655	1.0704	1.0743	1.0775	1.0802	1.0826	1.0846	1.0865	1.0881	1.0897	1.0910
170	1.0437	1.0537	1.0603	1.0653	1.0692	1.0724	1.0751	1.0774	1.0795	1.0813	1.0830	1.0845	1.0859
171	1.0427	1.0527	1.0593	1.0642	1.0681	1.0713	1.0740	1.0764	1.0785	1.0803	1.0820	1.0835	1.0848
172	1.0417	1.0517	1.0583	1.0632	1.0671	1.0703	1.0730	1.0754	1.0774	1.0793	1.0809	1.0825	1.0838
173	1.0406	1.0506	1.0572	1.0622	1.0661	1.0693	1.0720	1.0743	1.0764	1.0782	1.0799	1.0814	1.0828
174	1.0396	1.0496	1.0562	1.0611	1.0651	1.0683	1.0709	1.0733	1.0754	1.0772	1.0789	1.0804	1.0817
175	1.0386	1.0486	1.0552	1.0601	1.0640	1.0672	1.0699	1.0723	1.0743	1.0762	1.0778	1.0793	1.0807
176	1.0375	1.0475	1.0541	1.0591	1.0630	1.0662	1.0689	1.0712	1.0733	1.0752	1.0768	1.0783	1.0797
177	1.0365	1.0465	1.0531	1.0580	1.0620	1.0651	1.0678	1.0702	1.0723	1.0741	1.0758	1.0773	1.0786
178	1.0355	1.0455	1.0521	1.0570	1.0609	1.0641	1.0668	1.0692	1.0712	1.0731	1.0747	1.0763	1.0776
179	1.0344	1.0444	1.0510	1.0560	1.0599	1.0631	1.0658	1.0681	1.0702	1.0721	1.0737	1.0752	1.0766
180	1.0334	1.0434	1.0500	1.0549	1.0589	1.0621	1.0647	1.0671	1.0692	1.0710	1.0727	1.0742	1.0756
181	1.0324	1.0424	1.0490	1.0539	1.0578	1.0610	1.0637	1.0661	1.0681	1.0700	1.0716	1.0732	1.0745
182	1.0313	1.0413	1.0479	1.0529	1.0568	1.0600	1.0627	1.0650	1.0671	1.0690	1.0706	1.0721	1.0735
183	1.0303	1.0403	1.0469	1.0518	1.0558	1.0590	1.0616	1.0640	1.0661	1.0679	1.0696	1.0711	1.0725
184	1.0293	1.0393	1.0459	1.0508	1.0547	1.0579	1.0606	1.0630	1.0650	1.0669	1.0685	1.0701	1.0714
185	1.0282	1.0382	1.0448	1.0498	1.0537	1.0569	1.0596	1.0619	1.0640	1.0659	1.0675	1.0691	1.0704
186	1.0272	1.0372	1.0438	1.0488	1.0527	1.0559	1.0585	1.0609	1.0630	1.0648	1.0665	1.0680	1.0694
187	1.0262	1.0362	1.0428	1.0477	1.0516	1.0548	1.0575	1.0599	1.0619	1.0638	1.0654	1.0670	1.0683
188	1.0251	1.0351	1.0417	1.0467	1.0506	1.0538	1.0565	1.0588	1.0609	1.0628	1.0644	1.0660	1.0673
189	1.0241	1.0341	1.0407	1.0457	1.0496	1.0528	1.0554	1.0578	1.0599	1.0617	1.0634	1.0649	1.0663
190	1.0231	1.0331	1.0397	1.0446	1.0485	1.0517	1.0544	1.0568	1.0588	1.0607	1.0623	1.0639	1.0652
191	1.0220	1.0320	1.0386	1.0436	1.0475	1.0507	1.0534	1.0557	1.0578	1.0597	1.0613	1.0629	1.0642
192	1.0210	1.0310	1.0376	1.0425	1.0465	1.0497	1.0523	1.0547	1.0568	1.0586	1.0603	1.0618	1.0632
193	1.0200	1.0300	1.0366	1.0415	1.0454	1.0486	1.0513	1.0537	1.0557	1.0576	1.0592	1.0608	1.0621
194	1.0189	1.0289	1.0355	1.0405	1.0444	1.0476	1.0503	1.0526	1.0547	1.0566	1.0582	1.0597	1.0611
195	1.0179	1.0279	1.0345	1.0394	1.0434	1.0466	1.0492	1.0516	1.0537	1.0555	1.0572	1.0587	1.0601
196	1.0169	1.0269	1.0335	1.0384	1.0423	1.0455	1.0482	1.0506	1.0526	1.0545	1.0561	1.0577	1.0590
197	1.0158	1.0258	1.0324	1.0374	1.0413	1.0445	1.0472	1.0495	1.0516	1.0535	1.0551	1.0566	1.0580
198	1.0148	1.0248	1.0314	1.0363	1.0403	1.0435	1.0461	1.0485	1.0506	1.0524	1.0541	1.0556	1.0570
199	1.0138	1.0238	1.0304	1.0353	1.0392	1.0424	1.0451	1.0475	1.0495	1.0514	1.0530	1.0546	1.0559
200	1.0127	1.0227	1.0293	1.0343	1.0382	1.0414	1.0441	1.0464	1.0485	1.0504	1.0520	1.0535	1.0549
201	1.0117	1.0217	1.0283	1.0332	1.0372	1.0404	1.0430	1.0454	1.0475	1.0493	1.0510	1.0525	1.0539
202	1.0107	1.0207	1.0273	1.0322	1.0361	1.0393	1.0420	1.0444	1.0464	1.0483	1.0499	1.0515	1.0528
203	1.0096	1.0196	1.0262	1.0312	1.0351	1.0383	1.0410	1.0433	1.0454	1.0472	1.0489	1.0504	1.0518
204	1.0086	1.0186	1.0252	1.0301	1.0340	1.0372	1.0399	1.0423	1.0444	1.0462	1.0479	1.0494	1.0507
205	1.0076	1.0176	1.0242	1.0291	1.0330	1.0362	1.0389	1.0413	1.0433	1.0452	1.0468	1.0484	1.0497
206	1.0065	1.0165	1.0231	1.0281	1.0320	1.0352	1.0379	1.0402	1.0423	1.0441	1.0458	1.0473	1.0487
207	1.0055	1.0155	1.0221	1.0270	1.0309	1.0341	1.0368	1.0392	1.0413	1.0431	1.0448	1.0463	1.0476
208	1.0045	1.0144	1.0210	1.0260	1.0299	1.0331	1.0358	1.0381	1.0402	1.0421	1.0437	1.0453	1.0466
209	1.0034	1.0134	1.0200	1.0250	1.0289	1.0321	1.0347	1.0371	1.0392	1.0410	1.0427	1.0442	1.0456
210	1.0024	1.0124	1.0190	1.0239	1.0278	1.0310	1.0337	1.0361	1.0381	1.0400	1.0416	1.0432	1.0445
212	1.0003	1.0103	1.0169	1.0218	1.0258	1.0290	1.0316	1.0340	1.0361	1.0379	1.0396	1.0411	1.0425
215	0.9972	1.0072	1.0138	1.0188	1.0227	1.0259	1.0285	1.0309	1.0330	1.0348	1.0365	1.0380	1.0394
220	0.9920	1.0020	1.0086	1.0135	1.0174	1.0206	1.0233	1.0257	1.0277	1.0296	1.0312	1.0328	1.0341
225	0.9868	0.9968	1.0034	1.0083	1.0123	1.0155	1.0181	1.0205	1.0226	1.0244	1.0261	1.0276	1.0290
230	0.9816	0.9916	0.9981	1.0031	1.0070	1.0102	1.0129	1.0153	1.0173	1.0192	1.0208	1.0224	1.0237
235	0.9764	0.9864	0.9930	0.9979	1.0019	1.0050	1.0077	1.0101	1.0122	1.0140	1.0157	1.0172	1.0185
240	0.9711	0.9811	0.9877	0.9927	0.9966	0.9998	1.0025	1.0048	1.0069	1.0088	1.0104	1.0120	1.0133
245	0.9660	0.9759	0.9825	0.9874	0.9913	0.9945	0.9972	0.9996	1.0016	1.0035	1.0052	1.0067	1.0080
250	0.9606	0.9706	0.9772	0.9822	0.9861	0.9893	0.9920	0.9943	0.9964	0.9982	0.9999	1.0014	1.0028
255	0.9555	0.9655	0.9721	0.9770	0.9809	0.9841	0.9868	0.9892	0.9912	0.9931	0.9947	0.9963	0.9976
260	0.9502	0.9602	0.9668	0.9718	0.9757	0.9789	0.9816	0.9839	0.9860	0.9878	0.9895	0.9910	0.9924
265	0.9450	0.9550	0.9616	0.9665	0.9704	0.9736	0.9763	0.9787	0.9807	0.9826	0.9842	0.9858	0.9871
270	0.9397	0.9497	0.9563	0.9613	0.9652	0.9684	0.9710	0.9734	0.9755	0.9773	0.9790	0.9805	0.9819
275	0.9345	0.9446	0.9511	0.9560	0.9599	0.9631	0.9658	0.9682	0.9702	0.9721	0.9737	0.9754	0.9766
280	0.9292	0.9392	0.9458	0.9507	0.9547	0.9579	0.9605	0.9629	0.9650	0.9668	0.9685	0.9700	0.9714
285	0.9238	0.9338	0.9404	0.9454	0.9493	0.9525	0.9552	0.9575	0.9596	0.9615	0.9631	0.9647	0.9660
290	0.9186	0.9286	0.9352	0.9401	0.9440	0.9472	0.9499	0.9523	0.9543	0.9562	0.9579	0.9594	0.9607
295	0.9133	0.9233	0.9299	0.9349	0.9388	0.9420	0.9447	0.9470	0.9491	0.9509	0.9526	0.9541	0.9555
300	0.9080	0.9180	0.9246	0.9295	0.9334	0.9366	0.9393	0.9417	0.9437	0.9456	0.9472	0.9488	0.9501

Pressure of Steam in Pounds Absolute—Dry Saturated													Temperature of Feed Water Degrees Fahrenheit
25	135	145	155	165	175	185	195	205	215	225	235	245	
2266	1.2279	1.2292	1.2304	1.2315	1.2324	1.2333	1.2342	1.2351	1.2357	1.2365	1.2372	1.2378	32
2235	1.2248	1.2261	1.2273	1.2283	1.2293	1.2302	1.2311	1.2319	1.2326	1.2334	1.2341	1.2347	35
2183	1.2197	1.2209	1.2221	1.2232	1.2241	1.2250	1.2259	1.2268	1.2274	1.2282	1.2289	1.2295	40
2133	1.2145	1.2157	1.2170	1.2180	1.2189	1.2198	1.2208	1.2216	1.2222	1.2230	1.2238	1.2244	45
2080	1.2093	1.2106	1.2118	1.2128	1.2137	1.2147	1.2156	1.2164	1.2170	1.2179	1.2186	1.2192	50
2028	1.2042	1.2054	1.2066	1.2077	1.2086	1.2095	1.2104	1.2113	1.2119	1.2127	1.2134	1.2141	55
1977	1.1990	1.2002	1.2015	1.2025	1.2034	1.2044	1.2053	1.2061	1.2067	1.2076	1.2083	1.2089	60
1925	1.1939	1.1951	1.1963	1.1974	1.1983	1.1992	1.2002	1.2010	1.2016	1.2024	1.2031	1.2038	65
1874	1.1887	1.1900	1.1912	1.1922	1.1932	1.1941	1.1950	1.1958	1.1965	1.1973	1.1980	1.1986	70
1823	1.1836	1.1848	1.1861	1.1871	1.1880	1.1889	1.1899	1.1907	1.1913	1.1921	1.1929	1.1935	75
1771	1.1785	1.1797	1.1809	1.1820	1.1829	1.1838	1.1847	1.1856	1.1862	1.1870	1.1877	1.1883	80
1720	1.1733	1.1745	1.1758	1.1768	1.1777	1.1787	1.1796	1.1804	1.1810	1.1819	1.1826	1.1832	85
1668	1.1682	1.1694	1.1707	1.1717	1.1726	1.1735	1.1745	1.1753	1.1759	1.1767	1.1775	1.1781	90
1617	1.1630	1.1643	1.1655	1.1665	1.1675	1.1684	1.1693	1.1701	1.1708	1.1716	1.1723	1.1729	95
1566	1.1579	1.1591	1.1604	1.1614	1.1623	1.1633	1.1642	1.1650	1.1657	1.1665	1.1672	1.1678	100
1516	1.1528	1.1540	1.1552	1.1563	1.1572	1.1581	1.1591	1.1599	1.1606	1.1613	1.1620	1.1627	105
1463	1.1476	1.1489	1.1501	1.1511	1.1521	1.1530	1.1539	1.1547	1.1553	1.1562	1.1569	1.1575	110
1412	1.1425	1.1437	1.1450	1.1460	1.1469	1.1479	1.1488	1.1496	1.1503	1.1511	1.1518	1.1524	115
1360	1.1374	1.1386	1.1398	1.1409	1.1418	1.1427	1.1436	1.1445	1.1452	1.1459	1.1466	1.1472	120
1309	1.1322	1.1335	1.1347	1.1357	1.1366	1.1376	1.1385	1.1393	1.1400	1.1408	1.1415	1.1421	125
1257	1.1271	1.1283	1.1295	1.1306	1.1315	1.1324	1.1334	1.1342	1.1349	1.1356	1.1363	1.1370	130
1206	1.1219	1.1232	1.1244	1.1254	1.1264	1.1273	1.1282	1.1290	1.1298	1.1305	1.1312	1.1318	135
1154	1.1168	1.1180	1.1193	1.1203	1.1212	1.1221	1.1231	1.1239	1.1246	1.1253	1.1261	1.1267	140
1103	1.1116	1.1129	1.1141	1.1151	1.1161	1.1170	1.1179	1.1188	1.1195	1.1202	1.1209	1.1215	145
1052	1.1065	1.1077	1.1090	1.1100	1.1109	1.1119	1.1128	1.1136	1.1143	1.1150	1.1158	1.1164	150
1000	1.1013	1.1026	1.1038	1.1048	1.1058	1.1067	1.1076	1.1085	1.1092	1.1099	1.1106	1.1112	155
0948	1.0962	1.0974	1.0987	1.0997	1.1006	1.1015	1.1025	1.1033	1.1040	1.1047	1.1055	1.1061	160
0897	1.0910	1.0923	1.0935	1.0945	1.0955	1.0964	1.0973	1.0981	1.0989	1.0996	1.1003	1.1009	165
0845	1.0859	1.0871	1.0883	1.0894	1.0903	1.0912	1.0922	1.0930	1.0937	1.0944	1.0951	1.0958	170
0835	1.0848	1.0861	1.0873	1.0883	1.0893	1.0902	1.0911	1.0920	1.0927	1.0934	1.0941	1.0947	171
0825	1.0838	1.0850	1.0863	1.0873	1.0882	1.0892	1.0901	1.0909	1.0916	1.0924	1.0931	1.0937	172
0814	1.0828	1.0840	1.0853	1.0863	1.0872	1.0881	1.0891	1.0899	1.0906	1.0913	1.0921	1.0927	173
0804	1.0817	1.0830	1.0842	1.0853	1.0862	1.0871	1.0880	1.0889	1.0896	1.0903	1.0910	1.0916	174
0793	1.0807	1.0820	1.0832	1.0842	1.0852	1.0861	1.0870	1.0878	1.0886	1.0893	1.0900	1.0906	175
0783	1.0797	1.0809	1.0822	1.0832	1.0841	1.0850	1.0860	1.0868	1.0875	1.0882	1.0890	1.0896	176
0773	1.0786	1.0799	1.0811	1.0822	1.0831	1.0840	1.0849	1.0858	1.0865	1.0872	1.0879	1.0885	177
0763	1.0776	1.0789	1.0801	1.0811	1.0820	1.0830	1.0839	1.0847	1.0854	1.0862	1.0869	1.0875	178
0752	1.0766	1.0778	1.0791	1.0801	1.0810	1.0819	1.0829	1.0837	1.0844	1.0851	1.0859	1.0865	179
0742	1.0756	1.0768	1.0780	1.0791	1.0800	1.0809	1.0818	1.0827	1.0834	1.0841	1.0848	1.0854	180
0732	1.0745	1.0758	1.0770	1.0780	1.0790	1.0799	1.0808	1.0816	1.0824	1.0831	1.0838	1.0844	181
0721	1.0735	1.0747	1.0760	1.0770	1.0779	1.0788	1.0798	1.0806	1.0813	1.0820	1.0828	1.0834	182
0711	1.0725	1.0737	1.0749	1.0760	1.0769	1.0778	1.0787	1.0796	1.0803	1.0810	1.0817	1.0823	183
0701	1.0714	1.0727	1.0739	1.0749	1.0759	1.0768	1.0777	1.0785	1.0793	1.0800	1.0807	1.0813	184
0691	1.0704	1.0716	1.0729	1.0739	1.0748	1.0758	1.0767	1.0775	1.0782	1.0789	1.0797	1.0803	185
0680	1.0694	1.0706	1.0718	1.0729	1.0738	1.0747	1.0756	1.0765	1.0772	1.0779	1.0786	1.0793	186
0670	1.0683	1.0696	1.0708	1.0718	1.0728	1.0737	1.0746	1.0754	1.0762	1.0769	1.0776	1.0782	187
0660	1.0673	1.0685	1.0698	1.0708	1.0717	1.0727	1.0736	1.0744	1.0751	1.0758	1.0766	1.0772	188
0649	1.0663	1.0675	1.0687	1.0698	1.0707	1.0716	1.0725	1.0734	1.0741	1.0748	1.0755	1.0762	189
0639	1.0652	1.0665	1.0677	1.0687	1.0697	1.0706	1.0715	1.0723	1.0731	1.0738	1.0745	1.0751	190
0629	1.0642	1.0654	1.0667	1.0677	1.0686	1.0695	1.0705	1.0713	1.0720	1.0727	1.0735	1.0741	191
0618	1.0632	1.0644	1.0656	1.0667	1.0676	1.0685	1.0694	1.0703	1.0710	1.0717	1.0724	1.0731	192
0608	1.0621	1.0634	1.0646	1.0656	1.0666	1.0675	1.0684	1.0692	1.0700	1.0707	1.0714	1.0720	193
0597	1.0611	1.0623	1.0636	1.0646	1.0655	1.0664	1.0674	1.0682	1.0689	1.0696	1.0704	1.0710	194
0587	1.0601	1.0613	1.0625	1.0636	1.0645	1.0654	1.0663	1.0672	1.0679	1.0686	1.0693	1.0700	195
0577	1.0590	1.0603	1.0615	1.0625	1.0635	1.0644	1.0653	1.0661	1.0669	1.0676	1.0683	1.0689	196
0566	1.0580	1.0592	1.0605	1.0615	1.0624	1.0633	1.0643	1.0651	1.0658	1.0665	1.0673	1.0679	197
0556	1.0570	1.0582	1.0594	1.0605	1.0614	1.0623	1.0632	1.0641	1.0648	1.0655	1.0662	1.0668	198
0546	1.0559	1.0572	1.0584	1.0594	1.0603	1.0613	1.0622	1.0630	1.0637	1.0645	1.0652	1.0658	199
0535	1.0549	1.0561	1.0574	1.0584	1.0593	1.0602	1.0612	1.0620	1.0627	1.0634	1.0642	1.0648	200
0525	1.0539	1.0551	1.0563	1.0574	1.0584	1.0592	1.0601	1.0610	1.0617	1.0624	1.0631	1.0637	201
0515	1.0528	1.0541	1.0553	1.0563	1.0572	1.0582	1.0591	1.0599	1.0606	1.0614	1.0621	1.0627	202
0504	1.0518	1.0530	1.0543	1.0553	1.0562	1.0571	1.0581	1.0589	1.0596	1.0603	1.0611	1.0617	203
0494	1.0507	1.0520	1.0532	1.0542	1.0552	1.0561	1.0570	1.0579	1.0586	1.0593	1.0600	1.0606	204
0484	1.0497	1.0509	1.0522	1.0532	1.0541	1.0551	1.0560	1.0568	1.0575	1.0583	1.0590	1.0596	205
0473	1.0487	1.0499	1.0511	1.0522	1.0531	1.0540	1.0550	1.0558	1.0565	1.0572	1.0579	1.0586	206
0463	1.0476	1.0489	1.0501	1.0511	1.0521	1.0530	1.0539	1.0548	1.0555	1.0562	1.0569	1.0575	207
0453	1.0466	1.0478	1.0491	1.0501	1.0510	1.0520	1.0529	1.0537	1.0544	1.0552	1.0559	1.0565	208
0442	1.0456	1.0468	1.0480	1.0491	1.0500	1.0509	1.0519	1.0527	1.0534	1.0541	1.0548	1.0555	209
0432	1.0445	1.0458	1.0470	1.0480	1.0490	1.0499	1.0508	1.0516	1.0524	1.0531	1.0538	1.0544	210
0411	1.0425	1.0437	1.0449	1.0460	1.0469	1.0478	1.0487	1.0496	1.0503	1.0510	1.0517	1.0523	212
0380	1.0394	1.0406	1.0418	1.0429	1.0438	1.0447	1.0457	1.0465	1.0472	1.0479	1.0486	1.0493	215
0328	1.0341	1.0353	1.0366	1.0376	1.0385	1.0395	1.0404	1.0412	1.0419	1.0427	1.0434	1.0440	220
0276	1.0290	1.0302	1.0314	1.0325	1.0334	1.0343	1.0352	1.0361	1.0368	1.0375	1.0382	1.0388	225
0224	1.0237	1.0249	1.0262	1.0272	1.0281	1.0291	1.0300	1.0308	1.0315	1.0323	1.0330	1.0336	230
0172	1.0185	1.0198	1.0210	1.0221	1.0230	1.0239	1.0248	1.0257	1.0264	1.0271	1.0278	1.0284	235
0120	1.0133	1.0145	1.0158	1.0168	1.0177	1.0187	1.0196	1.0204	1.0211	1.0218	1.0226	1.0232	240
0067	1.0080	1.0093	1.0105	1.0115	1.0125	1.0134	1.0143	1.0151	1.0159	1.0166	1.0173	1.0179	245
0014	1.0028	1.0040	1.0053	1.0063	1.0072	1.0081	1.0091	1.0099	1.0106	1.0113	1.0121	1.0127	250
9963	0.9976	0.9989	1.0001	1.0011	1.0021	1.0030	1.0039	1.0047	1.0055	1.0062	1.0069	1.0075	255
9910	0.9924	0.9936	0.9948	0.9959	0.9968	0.9977	0.9987	0.9995	1.0002	1.0009	1.0016	1.0023	260
9858	0.9871	0.9884	0.9896	0.9906	0.9915	0.9925	0.9934	0.9942	0.9950	0.9957	0.9964	0.9970	265
9805	0.9819	0.9831	0.9843	0.9854	0.9863	0.9872	0.9881	0.9890	0.9897	0.9904	0.9911	0.9918	270
9754	0.9766	0.9778	0.9791	0.9801	0.9810	0.9820	0.9829	0.9837	0.9844	0.9852	0.9859	0.9865	275
9700	0.9714	0.9726	0.9738	0.9749	0.9758	0.9767	0.9776	0.9785	0.9792	0.9799	0.9806	0.9812	280
9647	0.9660	0.9672	0.9685	0.9695	0.9704	0.9714	0.9723	0.9731	0.9738	0.9745	0.9753	0.9759	285
9594	0.9607	0.9620	0.9632	0.9642	0.9652	0.9661	0.9670	0.9678	0.9686	0.9693	0.9700	0.9706	290
9541	0.9555	0.9567	0.9580	0.9590	0.9599	0.9608	0.9618	0.9626	0.9633	0.9640	0.9648	0.9654	295
9488	0.9501	0.9514	0.9526	0.9536	0.9546	0.9555	0.9564	0.9572	0.9580	0.9587	0.9594	0.9600	300

AUXILIARIES.

THE ELASTICITY AND ENDURANCE OF STEAM PIPES.

By C. E. STROMEYER. Paper read before the Institution of Naval Architects. Published in "Engineering," June 19, 1914. This article treats of the history of accidents to steam pipes and analyzes the causes of failures and the formulas on which strength of pipes are based. A thoroughly practical and instructive paper on this important subject.

"DOUST" PATENT EXPANSION JOINT.

The "Doust" patent expansion joint is entirely telescopic in its action, and has neither gland, packing nor rings. It thus has a flexibility unobtainable by any other expansion joint. It is adapted for steam (superheated and saturated) hot and cold water and oil pipes.

Four bushes of gun metal are employed. The two outer bushes have each a flange at one end, and are telescoped into one another. At the flange ends of outer bushes they are reduced in diameter, so that they fit on the inner bushes. The two inner bushes are also telescoped into one another, and have each a flange at one end. These flanges of the inner bushes come between the flanges of the outer bushes, and the flanges of the pipe to which the expansion joint is to be fitted. The accompanying drawing, Fig. 2, is a longitudinal section.

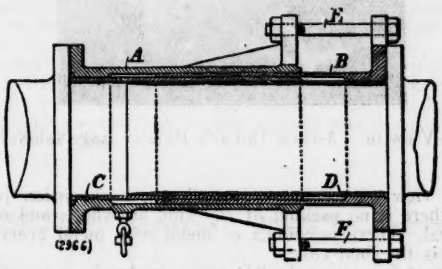


FIG. 2.—SECTION OF "DOUST" PATENT EXPANSION JOINT.

It will be seen that it consists of two outer shells A and B, which are respectively bolted to two flanges of the line of pipe, and inside these two shells are two liners C and D, which are secured in A and B, as shown in the illustration; they, however, slide a steam-tight fit one within the other, C being also a steam-tight fit in B, and B within M. The bolts E and F are merely to prevent undue motion. The cock is available for the purpose of ascertaining whether the inner sleeves are tight and, if required, for drainage purposes. The features of the joint are that it has no packing, which is a considerable item in the cost of upkeep. There is also no gland. It is claimed to be absolutely tight under all conditions,

and is specially suitable for pipes that are subjected to great variations of temperature. It is very sensitive in action, and is rapidly and easily fitted to any existing pipe arrangement. When once fitted up it requires no further attention, and cannot be tampered with.

This expansion joint has been standardized by the Board of Trade for steam working pressures up to 215 pounds per square inch and is approved by Lloyd's; it can also be supplied for steam working pressures up to 300 pounds per square inch. It is made to suit all sizes of pipes and is equally serviceable for high and low pressures—for main and auxiliary supplies. As will be noticed on reference to the illustration there are two outer shells and two inner liners, with flanges on the ends; bolts pass through the flanges of the pipes. With any alteration of length of range of pipes due to expansion or contraction they are free to work telescopically. Joints that have been in use for upwards of six years have given no trouble whatever and continue to give complete satisfaction. The small test cock can always be left open and serves two purposes: Of showing if the inner lines are tight, and of drawing off any water caused by possible condensation through the frequent opening and shutting off steam. In fitting this expansion joint it is necessary for the range of pipes to be anchored at both ends and that the alignment is correct, so that the expansion and contraction must be taken up by the joint. In the unlikely event of the inner liners giving out, the two outer shells will still keep the joint tight and permit of its working satisfactorily.

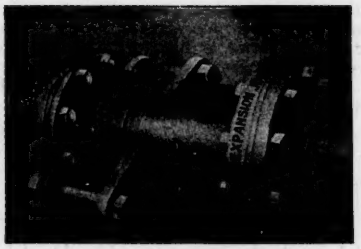


FIG. 3.—VIEW OF A 5-INCH DOUST'S PATENT EXPANSION JOINT.

Fig. 3 is a view of a 5-inch "Doust" patent expansion joint. It is claimed that there is no packing of any kind anywhere, and no parts requiring renewal. There is contact of metal with metal everywhere, and the first cost is the final cost.

During the past four years the "Doust" joint has been specified for new ships by several of the leading shipping companies, viz: The Peninsular and Oriental Steam Navigation Company (13 ships), the General Steam Navigation Company (2 ships), the Aberdeen Line (1 ship), the Orient Steam Navigation Company (1 ship), the Pacific Steam Navigation Company (3 ships), the Red Star Line (1 ship), the White Star Line (1 ship). The two first-named companies have adopted the "Doust" joint for all new ships.

The firm has recently received an order from Messrs. Harland & Wolff, Limited, for five 13½-inch, three 9½-inch, and six 7½-inch "Doust" expansion joints for the new Red Star liner S.S. *Belgenland*. The largest composite joints hitherto supplied were 11½ inches.—"Steamship."

COOLING OF THE LIQUID CO_2 IN REFRIGERATING MACHINES.

By F. A. Willcox, B. Sc., and G. C. Hodsdon, M. I. Mech. E.

OBJECT OF INVESTIGATION.

To determine the effect of various methods of reduction of the temperature of the liquid CO_2 after leaving the condenser and before reaching the regulator as regards (1) the coefficient of performance of the machine, and (2) the refrigerating capacity in relation to the swept volume of the compressor.

METHODS OF LIQUID COOLING.

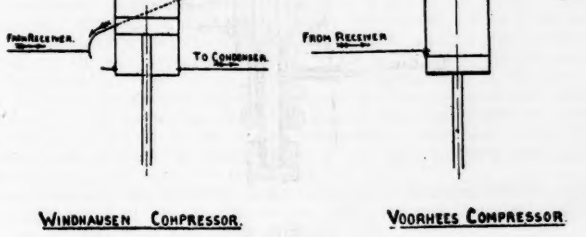
(1) The usual method employed is to bring the liquid in its course from the condenser to the regulator in contact with a current of water colder than that used for condensing the liquid in the condenser. This method is widely applied in land practice where atmospheric condensers are used and a small quantity of cold well water is available.

(2) There are cases in which machines must work constantly with water at a relatively high temperature, and in such cases evaporative cooling in two stages may be employed.

In this system the refrigerant splits up into two separate cycles. In the first or main cycle the liquid from the condenser passes through a regulating valve into a receiver, where it is cooled by the evaporation of the liquid which is passing through the second cycle. The cooled liquid in the first cycle passes through a second regulating valve to the evaporator and thence to the compressor.

In the second cycle the liquid from the condenser passes simultaneously with the liquid in the first cycle into the receiver. It is there completely evaporated, and in so doing cools the liquid in the first cycle. The vapor formed passes at a higher pressure than the vapor formed in the evaporator in the first cycle, either to the main compressor or to an auxiliary compressor.

This method of operating refrigerating machines was described by Linde in patent No. 1875 of 1890, by Windhausen in patent 9084 of 1901; by the latter with special application to CO_2 machines. A special type of compressor adaptable to this process was described by Voorhees in patent 4448 of 1905.



Windhausen Compressor. Voorhees Compressor.

Fig. 1.

Fig. 1 shows diagrammatically two compressors of the same swept volume of the Windhausen and Voorhees type. In the Windhausen system the gas is drawn from the evaporator on the down stroke; on the up stroke it passes to the other side of the piston, either through a passage or through valves in the piston, at the same time gas flows in from the receiver. On the return stroke the gas from the evaporator and from the receiver is discharged into the condenser. In the Voorhees compressor the gas is drawn from the evaporator on the down stroke, near the end of which ports connected to the receiver are uncovered, allowing gas to flow in from the receiver into the compressor. On the up stroke the gas is discharged into the condenser.

All these systems have been investigated by us, but it is proposed that this paper shall mainly be an account of the results obtained with the Linde or Windhausen process and the methods of obtaining them. Investigations have been carried out between the temperatures usual in the practice of refrigeration, but in order to keep the paper within reasonable limits it has been decided to confine the account to the brine temperatures usual in marine practice, viz: brine at 0 degrees F.

The paper is divided into the following subjects:

(1) Description of machine used for the investigations and the various combinations.

(2) Description of methods of measurement and discussion of limits of accuracy.

(3) Details of observations taken.

(4) Comparison of experimental results.

(5) Conclusions.

(6) Comparison of experimental results with results as calculated from Φi diagram.

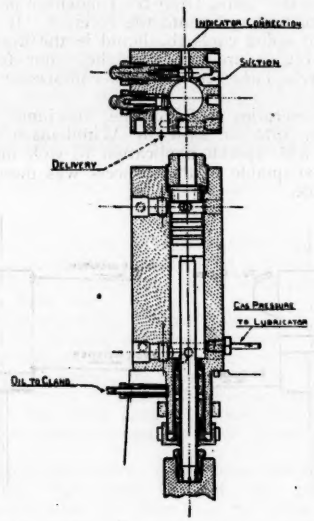


FIG. 2.

(1) DESCRIPTION OF PLANT.

The compressor used was of the vertical belt-driven type, 3-inch bore 9-inch stroke, as shown in Fig. 2, and driven by an electric motor. The condenser was of the submerged type, arranged so that the coil surface could be varied. The evaporator was of the submerged type, suitably insulated.

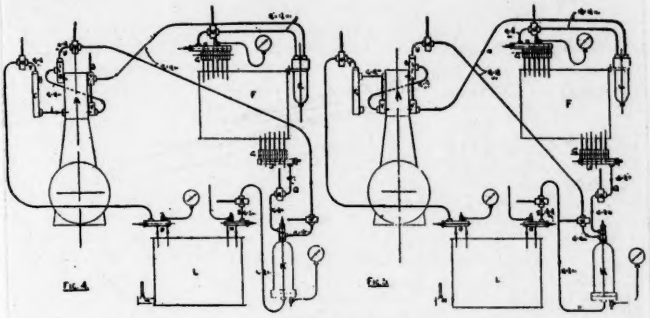


Fig. 4, diagram D, shows the arrangement when working on the Windhausen cycle, with the rod end of the compressor sucking from the evaporator.

Fig. 5, diagram E, shows the arrangement when working on the Windhausen cycle with the top end of the compressor sucking from the evaporator.

HEAT BALANCE.

The specific gravity of the brine was kept at 1.2 at 60 degrees F., and the specific heat taken at 8.5 B.t.u. per gallon per 1 degree F. This is probably slightly on the high side, but it is the same in all experiments.

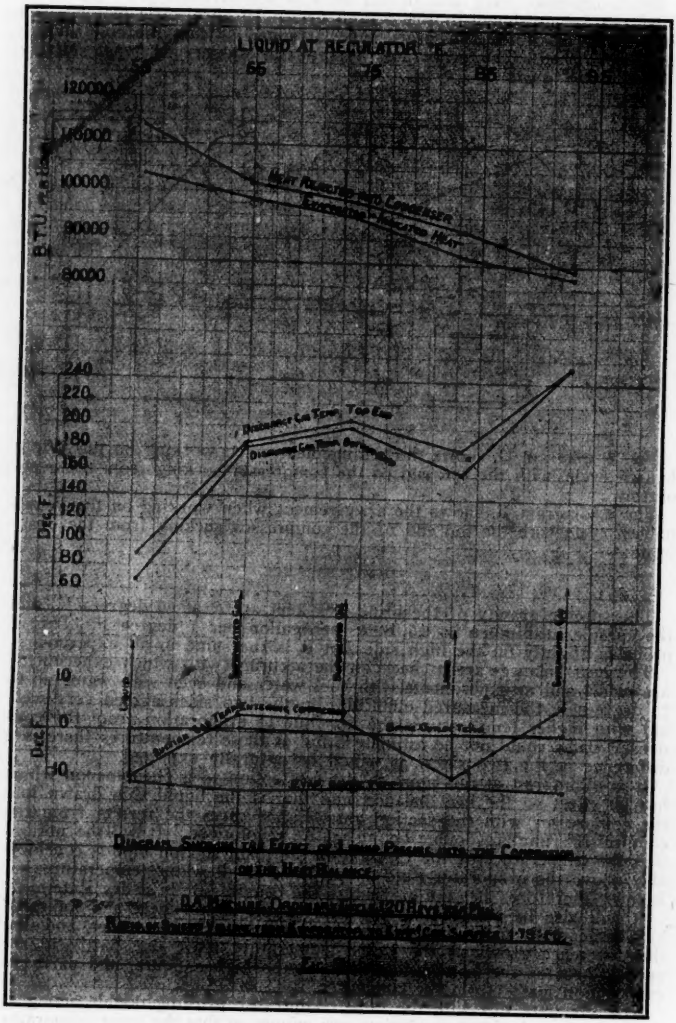
The heat balances are a check on the accuracy with which experiments are made, and in experiments with cool water and even with water up to 75 degrees F. the measured quantities on the two sides agreed very well, but with higher temperatures the loss due to evaporation from the condenser water could not be estimated, and at these temperatures there is a difference in the two sides, as would be naturally expected.

It is of interest at this point to draw attention to a phenomenon which has an effect on the heat balance, and that is the liquid CO_2 drawn into the compressor with the suction gas. Fig. 8 gives the results from the compressor running, double acting, at 67 revolutions. It will be noticed that the temperature of the CO_2 gas in the main suction pipe is considerably above the evaporator-gage temperature at all water temperatures; it follows, therefore, that the gas enters the compressor in a dry state.

It will also be noticed that the sum of evaporator heat and indicated heat is generally more than the heat rejected into the condenser, and that the difference grows as the water temperature rises, due partly to the specific heat of the brine being taken at too high a figure, and partly to evaporation losses from the condenser.

Now compare this with the same compressor working double acting at the higher speed of 120 revolutions per minute so that the same evaporator coil has to deal with 1.79 times as much CO_2.

Where the suction-gas temperature is below the brine temperature there are indications both from the gas-discharge temperature and from the


LIQUID AT REGULATOR °C.
65
75
85
120000
100000
80000
B.T.U. per hour
240
220
200
180
160
140
120
100
80
60
Deg. F.
10
0
-10
Deg. F.

heat balance that there is unevaporated liquid CO_2 passing into the compressor. Thus the greater the fall of temperature of the suction gas below the brine the lower is the temperature of the suction gas, such as one would expect when the suction gas is wet; at the same time there is a greater disturbance of the heat balance, which we suggest is due to unevaporated liquid passing through the evaporator and being evaporated by heat absorbed from the walls of the compressor and discharged as gas into the condenser.

This is borne out by the fact that the compressor becomes covered with snow or heavy condensation. In addition, therefore, to the heat normally rejected by the condenser it is called upon also to reject all the heat picked up by the liquid suction CO_2 from the time it leaves the evaporator. It is this which upsets the heat balance causing the condenser heat to exceed that of the evaporator heat and thermal equivalent of the power consumed.

It will be clear from this that the performance of a machine under certain conditions can be improved by increasing the coil surface in the evaporator or by fitting suction interchangers or liquid separators on the suction line. We have fitted suction interchangers in some large plants with advantage in that any liquid carried over from the evaporator is evaporated by cooling the liquid CO_2 on its way from the condenser to the regulator, dry gas thus going to the compressor.

CONCLUSIONS.

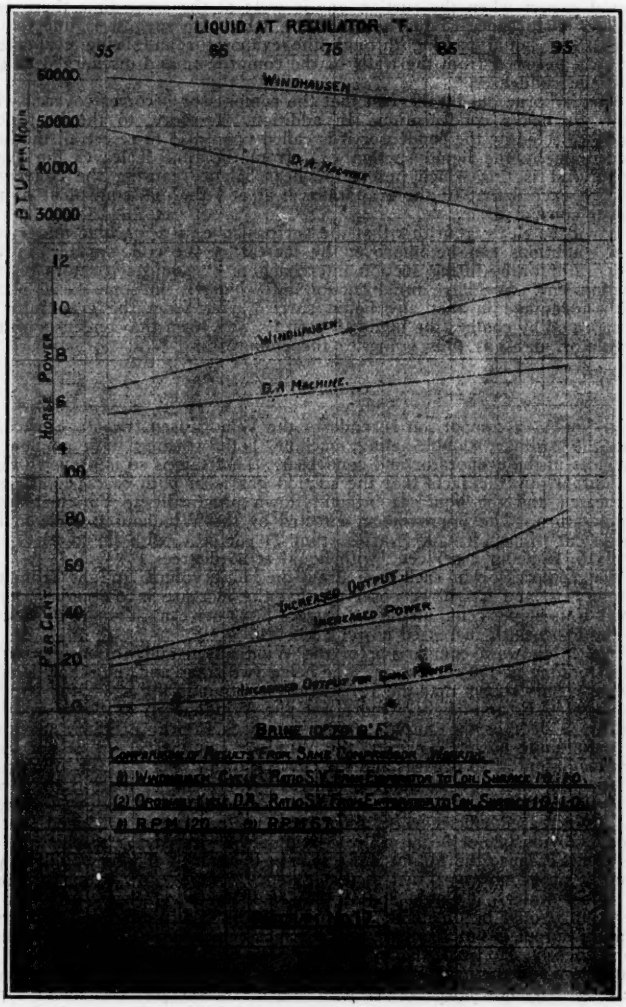
In Fig. 17 a comparison is made of the Windhausen two-stage machine and the ordinary double-acting machine, both working with ample coil surfaces in the evaporator and condenser. That this is so is proved (Figs. 11 and 14) by the facts that the suction gas is in both cases slightly superheated and the liquid is brought down practically to the inlet-water temperature. The improvement effected by the Windhausen cycle in the coefficient of performance varies from 25 per cent. with liquid at 95 degrees F. to about 2 per cent. with liquid at 55 degrees F.

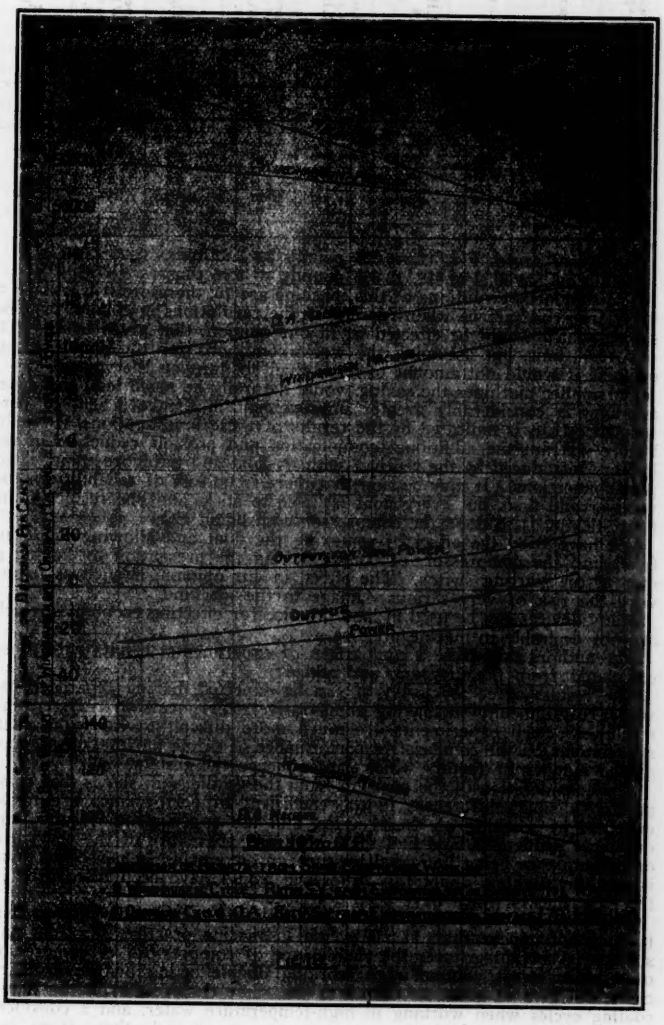
The compressor in each case drew the same volume of gas from the evaporator, and it will be observed that the increase in output at 95 degrees F. is 85 per cent., and at 55 degrees F. 23 per cent., though, of course, at the expense of increased power absorbed.

Fig. 18 shows a comparison of the Windhausen and ordinary machine both running at 120 revolutions, one being two-stage and the other double-acting. This shows that the refrigerative output is the same for both at 88 degrees F. and slightly more for the Windhausen at 95 degrees F. Below 88 degrees the output rapidly increases for the ordinary machine. For the same power, however, the Windhausen gives about 24 per cent. greater output at 95 degrees and the curve shows 10 per cent. at 55 degrees.

Applying this now to marine practice, where ample margin of power is always provided, it is apparent that at temperatures of about 88 degrees F. an increased efficiency of about 17 per cent. can be obtained, but it would obviously not be possible to reduce the size of the machine by 17 per cent. because the output must remain the same. There would simply then be an economy of fuel to that extent. Coming now to performance in colder waters, it would appear that an increased efficiency of about 10 per cent. would be obtained. But under these conditions the full refrigerating output is not required, and the machine is run at less revolutions; consequently the work the evaporator coils are called on to perform is much less and the evaporator more efficient, so that the saving shown will be only that shown by Fig. 17 with ample coil surface, viz: about 3 per cent.

In illustration of this point the following figures and calculated results are taken from the logs of one of our largest types of duplex machines on a voyage from Buenos Ayres to Southampton, extending over 28 days.


LIQUID AT REGULATOR, °F.
55
65
75
85
95
B.T.U. per Hour
60000
50000
40000
30000
WINDHAUSEN
D-A Machine
Horse Power
12
10
8
6
4
WINDHAUSEN
D-A MACHINE
Per Cent
100
80
60
40
20
0
INCREASED OUTPUT
INCREASED POWER
INCREASED OUTPUT PER EQUAL POWER
BRINE (OTHER R.C.)
Comparison of Results from Same Refrigerating Machine
(1) Windhausen Rated C.P. Ratio Six Tons Evaporation to Two Square Ins. Pis. 80
(2) Operating Under D.A. Ratio Six Tons Evaporation to One Square Inch Pis. 160
(1) R.P.M. 120 (2) R.P.M. 67



Average water Temp. °F.	Mean r.p.m.	Total hours run.	Total I.H.P. hours of steam engine.	Coal Consumption at 3 lbs. per I.H.P. hour.	Saving per ct. on Windhausen cycle. Fig. 17.	Saving lbs. coal. Fig. 17.	Saving per ct. on Windhausen cycle. Fig. 18.	Saving lbs. coal. Fig. 18.
1	2	3	4	5	6	7	8	9
53	32.9	149	7,900	23,800	2	474	11	2,607
60	22.2	144	5,630	16,890	4	676	9	1,520
72	32	192	11,850	35,550	7	2,488	10	3,555
70	41	168	13,900	41,700	11	4,587	12	5,004

Total coal saved, Fig. 17, 8,225 pounds = 3.67 tons.
Total coal saved, Fig. 18, 12,686 pounds = 5.66 tons.

The standard revolutions of this machine are 70, therefore it works on a very large coil surface when running at the revolutions in column 2. The saving which would be effected is, in our opinion, that given by Fig. 17, *i. e.*, 3.67 tons, but assuming the worst conditions for the double-acting machine it would not amount to more than six tons on the voyage.

On smaller machines the saving would naturally be much less, and, even assuming a considerably greater improvement in the coefficient of performance than is indicated by the results of these investigations, it would hardly warrant the additional complication and possible reduction in reliability introduced by the receiver with its float and the more complicated pipe connections. It may be said that there is no loss of reliability in the receiver and float, but every float is liable to stick, and one result of the float sticking is to flood the compressor with liquid CO_2.

We have tried the effect of removing the float and allowing liquid to flood into the compressor, of course, taking the precaution of having a man at the starting switch. The effect, in our opinion, is such as to invoke the risk of very serious damage to the machine.

Many devices can be used in land practice for effecting economies which are not desirable in marine practice.

The authors then gave a comparison of experimental results with those calculated from the diagram, and added:

The results agree as closely as can be expected, having regard to the very great difficulty in making comparative experiments in refrigerating machines. Such experiments are much more difficult to carry out than experiments on the comparative performance of prime movers, on account of the number of factors which can influence the results.

The consideration of the problem from the Φi diagram shows that comparatively small differences in the coefficient of performance are to be expected by working on these cycles, and the experimental results bear out these deductions, and had there been any possibility of the coefficient of performance being increased by such an amount as 50 per cent., there is not the slightest doubt this difference would have been discovered in the experiments which have been described.

The evaporative system of liquid cooling is of considerable interest, but it does not appear that, at all events in marine practice, it offers any substantial advantage over the simple type of compressor. A compressor of a given swept volume when working double acting on the ordinary cycle will give as great an output as the same compressor on the liquid cooling cycles when working in high-temperature water, and a considerably greater output in lower temperatures, consequently there is no advantage from this point of view. The saving in coal consumption in small machines would be an insignificant quantity, and even in the largest machines on average voyages is in our opinion not sufficient to warrant the

extra complication. Vessels may, however, be engaged in trades in which they are continuously in high-temperature water, when this method of liquid cooling might possibly be of advantage. In land practice there are cases where it may be used with some advantage, and we are making machines to meet such conditions, and we hope shortly to make comparative tests on one of much larger size than that used for these experiments. But even in land practice the cases are rare where a liquid cooler of the coil type cannot be applied, and it is owing to the general application of this type of liquid cooler that the evaporative cooler has not been to any considerable extent applied in practice.

Table 1.

(1)	Experiment number	241	245
(2)	Water inlet, °F	85.14	54.45
(3)	Water outlet, °F	90.20	98.22
(4)	Liquid at regulator, °F	85.30	61.6
(5)	Gallons water per hour	2,460	310
(6)	Brine inlet, °F	30.23	30.31
(7)	Brine outlet, °F	20.00	20.11
(8)	Discharge pressure indicated lb. sq. in	1,210	1,185
(9)	Suction pressure indicated lb. sq. in	355	345
(10)	Suction gas from evaporator, °F	11.5	11.2
(11)	I.H.P. of compressor	14.22	13.14
(12)	Heat abstracted from evaporator	92,400	104,000
(13)	Heat equivalent of I.H.P	36,200	33,400
(14)	(12) plus (13)	128,600	137,400
(15)	Heat rejected into condenser, measured	124,500	137,000
(16)	Loss due to radiation from condenser	6,900	3,000
(17)	(15) plus (16)	131,400	140,000
(18)	(17) plus (14)	2,800	2,600
(19)	Increase in output for same power, per cent		21.6

—"Cold Storage."

PROVIDENCE CENTRIFUGAL PUMP.

Centrifugal pumps in two styles—the double suction for generating moderate heads and the multistage for greater heads—are built by the Providence Engineering Works, Providence, R. I.

Their characteristics of design are accessibility to all wearing parts without disturbing the pipe connections, simplicity of construction and operation, easy connections to the suction and pressure mains, and a properly designed passage throughout the pump and impeller to insure an undisturbed flow of fluid. All the parts subject to wear are easily removed and renewed; they may be furnished by the manufacturer or made by the user of the pump if it is more convenient.

The pump casing is split on a plane passing through the shaft axis, so that the upper casing may be removed without disturbing any pipe connection when inspecting the pump interior. The lower casing has flange openings below the shaft for the suction- and discharge-pipe connections. This arrangement makes it easy to connect the pump and the pipes are out of the way. Fig. 2 is an exterior view of the multistage pump connected to a motor. The design of the pump is so simple that it can be stopped, opened, inspected, closed and made ready to start in less than 45 minutes.

The suction duct is so disposed as to lead the incoming current smoothly and at a uniform rate through the inlet flange and bring it in a compact mass up to the inner edges of the impeller vanes. As the liquid is pro-

tected from the rotating effect of the impeller hub, it enters undisturbed in a radial direction into the rotating-vane passages, where the vanes impart to it a gradually increasing degree of rotation, finally delivering it into the discharge chamber. This is one of the main features of the pump and much attention has been given to its design, so that the water must reach the impeller vanes in a compact and undisturbed state. This action will increase the pump capacity over what it would be if the liquid was disturbed by contact with the extensive surfaces of the impeller hub and web.

The method of protecting the incoming water from the action of the impeller hub is shown in Fig. 1, a sectional view of a multistage pump. The inlet duct terminates in a conical shell extending close to the impeller vane. This shell is of bronze, except where ammonia liquors are handled, in which case the apparatus is made of cast iron.

As shown in Fig. 1, the casing is shaped to make the travel from the periphery of the impeller through the discharge flange as direct as possible and it is proportioned to permit gradual and unhindered reduction of the jet velocity.

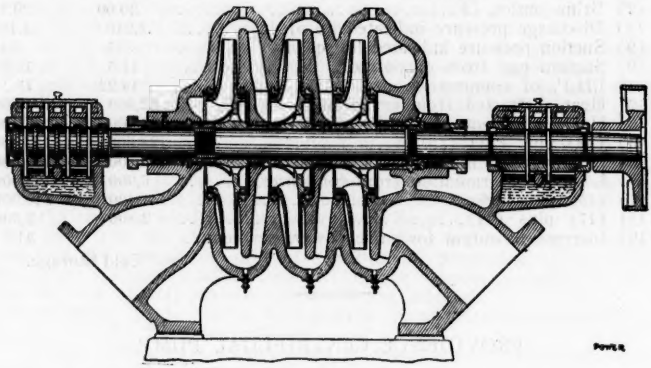


FIG. 1.—SECTION THROUGH MULTISTAGE PUMP.

The two parts of the casing are bolted together with a manila-paper gasket between. The gasket is shellacked to the lower casing and covered with graphite paste on the upper side, which readily allows removing the upper casing without destroying the gasket.

The impeller is of the inclosed type, in which the sides of the vanes are cast integrally. The vane passages are spaced to suit the working conditions imposed, and are hand finished; the outer sides of the hub of the impeller are machined. The impellers are made to suit the wear and corrosion according to the liquid to be handled; generally, they are made of gun metal. On each side and surrounding the inlet opening the impeller is fitted to receive packing rings of the same material as the impeller. The impeller is keyed to the shaft and adjusted to permit its easy removal when necessary.

Leakage from the impeller chamber into the inlet chamber cannot be prevented, but it is checked by means of radial labyrinths between the inner walls of the impeller and the casing walls. This feature is shown in Fig. 1. In Fig. 3 are shown details of the radial-impeller labyrinths which are used exclusively in these pumps. They allow the slight eccentric movement of the rotating member without altering the efficiency

of the joints. The lateral clearance is preserved through careful hydraulic balancing of the rotating parts and adjustment of the thrust bearings. What leakage takes place does not interfere with the incoming current and mingles with it a short distance before their common entrance into the impeller proper. The casing labyrinths are composed of rings made in halves, and each is so fastened that when the pump cover is removed for inspection the upper halves of the casing rings remain attached to the cover, thus allowing an unhindered view of the surfaces of the other parts; that is, the impeller ring which screws on each side of the impeller, as shown in Fig. 3.

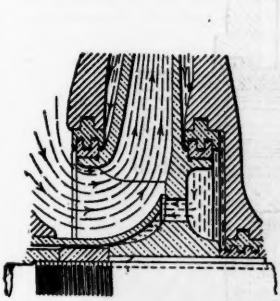


FIG. 3.—RADIAL IMPELLER LABYRINTH.

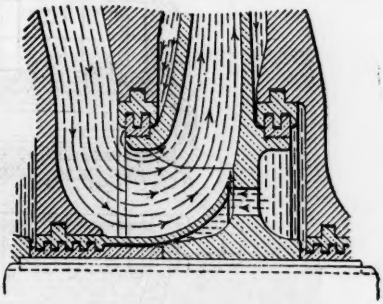


FIG. 4.—DIAPHRAGM LABYRINTH.

On either side the impeller has labyrinth rings to prevent leakage from the discharge chamber into the impeller intake, but in the multistage pump two adjacent pieces are separated by a diaphragm having an opening through which the shaft passes. This is shown in Fig. 4.

The casing shell of the radial labyrinth is split so that the upper half (it is held in the pump cover in the same manner as the impeller-casing labyrinth) is attached when the cover is removed; all the parts subject to wear are accessible for examination. The casing shell extends into the inlet chamber of the next impeller and also serves as a guide wall, thus leading the incoming liquid into the impeller passages and preventing the contact of the liquid with the rotating surfaces of the impeller web and hub. The axial clearance between the labyrinth flanges is the same as in the impeller labyrinth, while the radial clearance is sufficient to accommodate any ordinary eccentric motion of the shaft. The bronze casing, impeller and diaphragm labyrinths, for ordinary conditions, are composed of 88 parts copper, 10 parts tin and 2 parts zinc.

The bearings are in brackets cast integral with the lower part of the pump casing, one being plain and the other a combination of plain and marine thrust bearings. The plain bearing is a split cast-iron shell lined with babbit and arranged for ring oil lubrication; it is located usually near the driving end and the other is then outboard. The bearing shell can be rebabbitted by any mechanic. The outboard, or combination bearing, known as a thrust bearing, Fig. 5, is a split, cast-iron shell, grooved and babbitted to accommodate a removable and renewable steel thrust sleeve carried by the shaft. This sleeve has thrust collars which fit babbitted grooves in the shell. Between any two adjacent collars there is an oil ring which lubricates the plain parts of the sleeve as well as the sides of the two collars.

One end of the shell is provided with a bolt-and-thimble attachment whereby close adjustment of the bearing as to the thrust collar can be had and maintained. Both bearings are readily accessible for inspection by

simply removing the caps and lifting the upper shells which expose the wearing surfaces of the shaft. The design of the shell is such that the upper one can be easily removed and then the lower ones may be turned around the shaft and also removed without trouble. The caps are cored out so that, in case hot liquids are handled, they can be connected to a cold-water system and the bearings thus cooled through contact of the upper bearing with the inner surface of the cap.

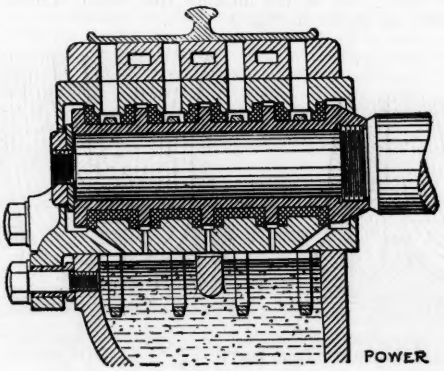


FIG. 5.—THRUST BEARING.

The shaft is protected from contact with the liquid passing through the pump by the impeller hub and locking nut. The rest of the shaft, on both sides of the impeller and that which passes through the stuffing boxes, is protected by sleeves screwed to the shaft itself and extending past the packing. These sleeves are removable and renewable, and of material which will withstand the action of the various liquids handled.

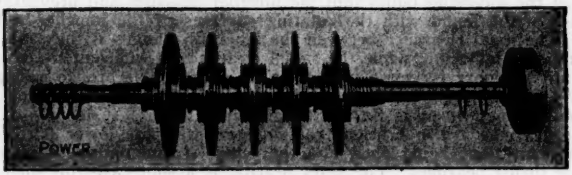


FIG. 6.—ROTATING PARTS OF THE PUMP.

The rotating parts of the pump, Fig. 6, are balanced, first on parallels and eventually by speed trials without handling water. With the double-suction pump both sides of the impeller are symmetrically disposed, thus an equal amount of water may traverse each side of the impeller from the suction chamber to the discharge chamber.

The hydraulic balancing of the multistage pump is obtained (a) by symmetrically disposing the impeller labyrinths on each side of each impeller; (b) by providing communication from the balancing chamber

formed on the rear of each impeller through the web and into the impeller inlet proper, so as to cause the pressure to be practically the same at these two points and that the liquid traversing from one to the other does not disturb the flow of liquid entering the impeller passages; and (c) by having on the high-pressure side of the pump a labyrinth pressure-reducing device. This materially assists the operation of the packing in the stuffing box, because the soft packing is practically under the same pressure as at the suction end. This labyrinthine device leads into a small chamber which communicates with a suction duct through a small pipe having a regulating valve. A slight adjustment of this valve suffices to counteract any imperfections in the ordinary balancing of the pump which might develop during irregular operation.

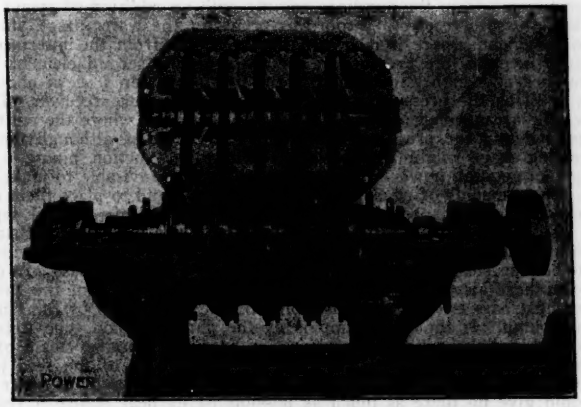


FIG. 7.—MULTISTAGE PUMP WITH COVER LIFTED.

Referring to Fig. 7, it will be seen that the pump-bed plate is of very light construction since ordinarily it is to be grouted onto solid foundations, the manufacturers believing that in many places the first cost may be reduced appreciably by omitting the cast-iron base and mounting the pump and its motor directly upon a concrete foundation as, except when engine driven, heavy and expensive foundations are not required. Besides, experience has shown that, no matter how heavy the bed plate may be, whenever the pump or its prime mover gets out of alignment, due mostly to stress in the piping, the bed plate is never ungrouted, but, instead, the pump is shimmed up or suitably shifted until the alignment is again obtained. This points to a possible reduction in first cost through the omission of a bed plate whenever feasible.—"Power."

FEED HEATING.

HIGH FEED-WATER PREHEATING ON STEAMERS (*Hohe Speisewasservorwärmung auf Dampfern*, Ofterdinger, "*Zeits. des Vereines deutscher Ingenieure*," vol. 58, no. 16, p. 617, April 18, 1914, 5 pp., 2 figs. *deA*). The

author presents a new method of preheating boiler feedwater particularly adapted to use on steamers. He proposes to preheat the water by exhaust steam from auxiliary engines and receiver steam to a temperature of 140 degrees C. (284 degrees F.) and higher. The advantage of such high preheating of feedwater lies first in the improvement of the efficiency of the engine plant, and second in the beneficial action on the life of the boiler, which is in this way spared from the heavy stresses consequent upon the injection of comparatively cold water. In addition, the higher the temperature of the water the freer it is from air, which is objectionable when present in the boiler. For such high preheating of the feedwater two-stage preheaters in series are used, working on steam of different pressures. When such preheaters are used in connection with triple or quadruple-expansion engines, they may first be heated by the exhaust steam from the auxiliary engines with an addition of steam from the low-pressure receiver. From this preheater the water passes into the second element, where it is heated by the steam from the intermediate-pressure receiver, the pressure of the steam in the second element being maintained at a higher level than in the first preheater, *i. e.*, at about the same level as the pressure in the intermediate-pressure receiver. Fig. 8 shows the arrangement of such two-stage preheaters, where the entire set is inserted into the pressure piping of the feed pump, although the first preheating stage might also be inserted into the suction piping of the pump. In general, however, it would appear to be advisable to make both preheating elements of equal size and construction and to place them on to the pressure piping, providing them with means for air and oil separation. To regulate the pressure of the heating steam in the second stage a throttling valve is provided, so arranged that the water of condensation of the heating steam, but not the steam itself, is allowed to pass. In order to avoid heat losses the entire water of condensation from the heating steam must pass into the suction piping of the feed pump or the tank of the air pump. If the feed pump is of the plunger-piston type it is advisable to lead the water of condensation from the heating steam of the second preheater stage not directly to the suction side of the feed pump but into the heating steam space of the first preheater stage, in order that it should give up there as much as possible of its heat before it reaches the feed pump together with the rest of the water of condensation from the first preheater stage. In this way the feedwater at the suction end of the pump remains comparatively cool, notwithstanding the high degree of preheating on the pressure side of the pump, which is of importance for the good working of the feed pump.

The following tests were made to show the advantages derived from higher superheating of feed water by two-stage preheater arrangement involving the use of steam from an intermediate-pressure receiver. The boiler was provided with artificial draft (Howden process) and Schmitt superheaters and had the following dimensions: heating service of boiler in contact with water, 396 qm.; grate area, 95 qm. (1,021 square feet); heating service of superheater in contact with steam, 182 qm. (1,959 square feet); and steam pressure, 13.5 atmospheres. The main engine was a triple-expansion vertical marine engine with surface condensation and pumps driven by connecting beams and had the following dimensions: stroke, 1,050 mm. (41.3 inches); diameter of high-pressure cylinder, 600 mm. or 23.6 inches; intermediate cylinder, 970 mm. (38.1 inches); and low-pressure cylinder, 1,575 mm. (61.8 inches). The two-stage feed-water preheater was inserted into the pressure piping of the feed pump, the heating area in either stage being 7.5 qm. (80.7 square feet), thus making a total of 15 qm. (161.4 square feet).

Two tests have been made. In test A the plant was run with preheating of feed water by exhaust steam from the auxiliary engines and receiver steam from the low-pressure receiver in the first stage and by intermediate-pressure receiver steam in the second stage. In test B, the plant was

run in the same manner as in test A, but the heating steam from the intermediate-pressure receiver was cut off and only the first stage of the preheater was working (in the same manner as in test A). The degree of admission in the steam cylinder was the same in both cases. The data obtained in the tests are shown in Table 5, while Table 6 gives the comparison of the data of the two tests recalculated. The feed water in the first test was heated to 126 degrees C. (258.8 degrees F.) and in

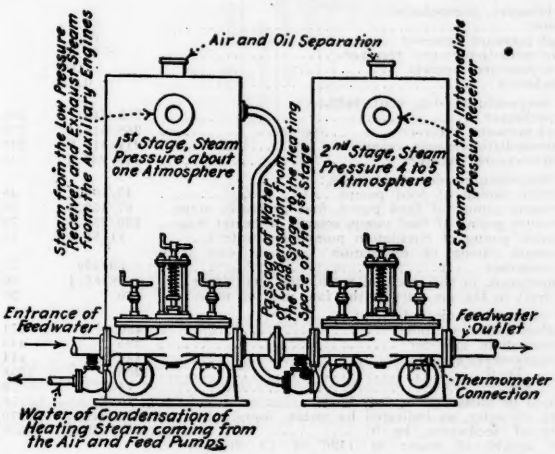

Steam from the Low Pressure Receiver and Exhaust Steam from the Auxiliary Engines
Air and Oil Separation
1st Stage, Steam Pressure about one Atmosphere
Passage of Water of Condensation from the 2nd Stage to the Heating Space of the 1st Stage
2nd Stage, Steam Pressure 4 to 5 Atmosphere
Steam from the Intermediate Pressure Receiver
Entrance of Feedwater
Feedwater Outlet
Thermometer Connection
Water of Condensation of Heating Steam coming from the Air and Feed Pumps

FIG. 8.—TWO-STAGE FEED-WATER PREHEATER.

test B to 79 degrees C. (174.2 degrees F.). No measurement of coal consumption was made, but the water returned by the feed pumps to the boiler was measured by a water meter of the Kegley type. The heat consumption calculated from these values gives a more reliable basis for the estimation of the operating conditions present than would be possible to make from the measurement of coal consumption. During the tests A and B no auxiliary feed water was admitted. The heat-consumption figures per indicated horsepower hour given in Table 6 seem to be too good, but, for the purpose of comparison between the two, this does not matter. Heat losses which occur during the test may be assumed to be distributed evenly over the entire duration of the tests. During both tests the ventilation machinery, steering-gear engine, and ash hoist were driven by steam, the ventilation constantly, steering gear as necessary, and the ash hoist to lift from 22 to 24 buckets at each test; the weather was good, the sea nearly quiet and the steering-gear engine only little used. The author reports also control data obtained from an investigation of indicator diagrams taken during the same tests. Both methods indicated a heat saving of from 3 to 4.2 per cent., when the temperature of feed water is maintained at from 126 to 136.5 degrees C. (258.8 to 277.7 degrees F.). The cause of the heat saving lies in the high latent heat of steam. The steam from the intermediate-pressure receiver proceeds to do further work in the intermediate and low-pressure cylinders of the engine (having regard to the heat which reaches a boiler

TABLE 5.—DATA OF TESTS OF FEED WATER PREHEATING, ONE AND TWO STAGE.

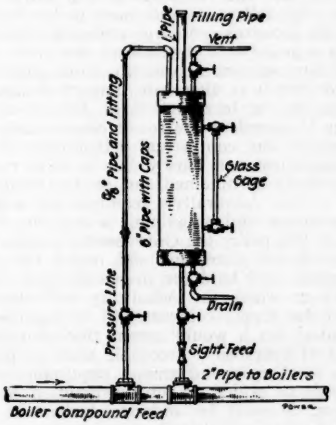
	Test A	Test B
Duration of test, hours	3	3
Admission, per cent.:		
High-pressure cylinder	62	62
Intermediate cylinder	37	37
Low-pressure cylinder	42	42
Steam pressure, atmospheres:		
Boiler	13.8	13.7
High-pressure receiver	13.1	13.0
Intermediate-pressure receiver	5.65	6.05
Low-pressure receiver	1.69	1.70
Condenser	0.15	0.15
Steam temperatures, deg. cent./fahr.:		
Superheater	285/545	295/563
High-pressure receiver	268/514.4	278/532.4
Intermediate-pressure receiver	214/417.2	222/431.6
Low-pressure receiver	113/235.4	115/239
Water temperatures, deg. cent./fahr.:		
Suction piping of feed pumps	43/109.4	48/118.4
Pressure piping of feed pump, first preheater stage	67/152.6	76/168.8
Pressure piping of feed pump, second preheater stage	126/258.8	79/174.2
Suction piping of circulation pump (sea water)	11/51.8	10/50
Pressure piping of circulation pump at exit from condenser	50/122	51/123.8
Air temperature in the machine room, deg. cent./fahr.	28/82.4	30/86
Boiler draft in the air duct at the fan, mm. of water	30	30
Engine output in indicated H.P.:		
High-pressure cylinder	430	371
Intermediate cylinder	395	443
Low-pressure cylinder	440	444
Total	1265	1258
Speed, r.p.m.	74.3	74.4
Ship speed as measured by log, knots	10.7	10.8
Quantity of water, as indicated by meter, liters/gal.	20620/5493	18870/4983
Quantity of feedwater, kg./h.	19362/42596	18332/40330
Specific weight of water at 1126 or 79 degrees C. respectively	0.939	0.972

TABLE 6.—RECALCULATED DATA OF TABLE COMPARED.

	Test A	Test B
Boiler pressure, atmospheres	13.8	13.7
Steam temperature in superheater, deg. cent./fahr.	285/545	295/563
Average engine output, I.H.P.	1265	1258
Steam consumption:		
Total, kg./lb.	19362/42596	18332/40330
per h.p.-hr.	5.102/11.22	4.86/10.69
Heat generation, WE/B.t.u.:		
of steam coming from the superheater	721.3/2863.5	726.6/2884.6
of feed water from the boiler	126/490.2	79/313.6
Heat supplied to working fluid in boiler and superheater, WE/B.t.u.:		
(*a*) per kg./lb. of feed water	595.3/1071.5	647.6/1165.6
(*b*) per i.h.p.-hr.	3037/5466.6	3147/5664.6
Saving in heat in test A as compared with test B, per cent.	3.5	

with the feed water) at thermal efficiency of about 12 per cent., while the steam which is taken from the intermediate-pressure valve casing and used for the higher preheating of the feed water is returned to the boiler with the utilization of at least 90 per cent. of its heat. This difference in the efficiency of utilization of part of the steam accounts for the better saving of heat with the two-stage preheater.—"Journal Am. Soc. of Mechanical Engineers."

BOILER-COMPOUND FEEDER.



FEEDER CONNECTED.

A boiler-compound feeder to be connected to the discharge line of the feed pump is shown in the illustration. It should be set above the feed line to get enough static head, which, plus the pump pressure, will be sufficient to discharge the contents. Perhaps this is not a new idea, but it may be of value to some one.—"Power."

OIL.

OIL FUEL FOR THE NAVY.

The negotiations which the Government have been carrying out with the Anglo-Persian Company have been dealt with in a Parliamentary Blue Book issued about the beginning of June, 1914. It will be remembered that the First Lord, in dealing with the estimates for the Navy, emphasized the importance of some arrangement whereby provision can be made for oil fuel, which will, without doubt, become an absolute necessity in order to secure the full efficiency of his Majesty's Naval service. Further, it was about a year ago that the First Lord stated to Parliament that a necessary part of the ultimate policy of the Admiralty must be that the Government should become the owners, or at any rate the controllers at the source, of at least a proportion of the natural oil which the Navy required, and to spread contracts for the supply as much as possible over widely separated fields, so that in time of war if some areas should be closed others will remain open. While it is not desirable to draw all our supplies from one source, it was essential that the fields over which His Majesty's Government will have control should be so developed that in times of emergency they will be able to supply, at short notice, any deficiencies that may arise through the failure of deliveries elsewhere. It can only be by such control that the state can ensure that prices shall not

be artificially inflated by interested producers and marketing agencies, as the evident tendency for the oil fields of the world and the marketing of their products is to fall more and more under the control of a comparatively few large concerns. A large consumer like the Admiralty cannot place itself in a position of dependence for vital supplies upon a few companies whose interests are necessarily cosmopolitan and financial. It will be recognized that it is, therefore, important and essential in naval interests to secure that at least one large British oil company shall be maintained, having independent control of considerable supplies of natural petroleum, by financial and contractual obligations. It will be recognized that such an arrangement can hardly fail to have its effect, not merely on the supplies, directly so obtained, but on the terms and conditions on which the whole of the Admiralty's requirements will be met, owing to the greater independence and bargaining power thus obtained.

In furtherance of this policy the Government propose to invest £2,000,000 in the Anglo-Persian Oil Company, and under the arrangements to be made the Government will hold the preponderating interest in the share capital. The price at which the Admiralty will obtain the oil itself is kept a secret, and the supply contract will be regarded in the public interests as confidential, but it would appear that provision is made for the supply for a term of years on a favorable scale of price of a reasonable proportion of the total estimated annual requirements of the Admiralty, on the present basis of policy of oil consumption and with due allowance for expansion. It must be understood that the contract is for oil only and the Admiralty will therefore make its own arrangements for transport. This procedure is, of course, a departure from the usual, and must obviously have been carried out in connection with and under the authority of the Treasury, and it will be interesting to see how far the Treasury are prepared to go in the direction of Imperial trading for providing fuel for the Navy in the future. It does not appear to us to be correct to assume, as has been done in some quarters, that this deal has been effected for the purpose of supplying oil fuel for vessels in the Eastern waters only, as it is quite clear to us from the broad outline of policy involved, that having got a first claim to oil, for which the Admiralty no doubt would have to pay what is substantially the market price, they can ship that oil either to this country or any convenient basis where it is desirable to store it. We do not think that any level-headed business man will cavil at the foresight of the Admiralty or with their method of dealing with the provision of a necessity on which the efficiency of the Navy largely depends.

Although the agreement referred to is made, signed and sealed, it follows that the necessary resolutions by the existing shareholders on the one side, must be passed, and on the other the funds needed for giving effect to it must be provided by Parliament. We understand that a financial resolution and a money bill are in the ordinary course to be brought before Parliament for the latter purpose, the intention being to issue the Government capital by instalments as required.—"Marine Engineer and Naval Architect."

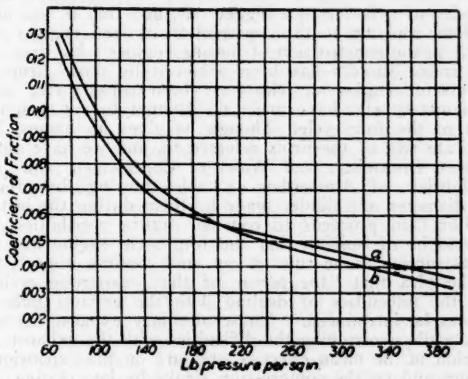
TESTS OF FILTERED OIL.

Tests of lubricating oil made by the Richardson-Phoenix Company, Milwaukee, Wis., recently proved that if oil is properly filtered it can be used over and over again indefinitely without losing any of its lubricating qualities.

The power plant of a New York hotel is equipped with a Richardson central oiling and filtering system, supplying lubrication to four engines, four air compressors, and a crank and fly-wheel pump, with a grand total

of 134 points of lubrication. The plant operates continuously, and the average temperature of the engine-room is 100 degrees F. On account of the great variety of machines lubricated, the high load factor, and the exceptional temperature conditions, the work imposed on this lubricating system is probably as severe as can be found in any power plant. The average amount of oil handled by the lubricating system was 150 gallons per hour, or about 1,800 barrels per month. Although this large amount of oil is supplied continuously to the bearings, it is stated that it is only necessary in this plant to add about three barrels of oil per month, and even this quantity cannot be charged to natural shrinkage in the system, as large quantities of oil are drawn off from the filters and used in cans for the hand-oiling of small pumps, valve gears, and other bearings not connected with the oiling system.

To determine the changes undergone by the oil, a sample of the new oil, as received in barrels from the manufacturers, was secured, and a sample of oil was also drawn off from the clean-oil compartment of the filter. These were sealed in the engine room and shipped to the testing department of Cornell University, where a series of tests were made without any further purification or filtration. A number of friction tests were made on a railroad lubricant tester, having a hardened-steel journal and bronze bearings with a total area of 20 square inches. In all the tests the testing machine was run at a constant speed of approximately 360 revolutions per minute, and the load applied in increments of 75 pounds per square inch, until a total pressure of 1,500 pounds was reached. The test at each load was continued until the friction and temperature of the bearing were constant. The oil was fed upon the side of the bearing through a sight-feed oiler, and the feed maintained as nearly constant as possible throughout the tests. The results of the tests for the coefficient of friction are presented in the accompanying diagram, the new oil being shown in the curve *a*, while the filtered oil is represented by the curve *b*.



TESTS OF FILTERED OIL.

Tests were also made to determine what physical changes, if any, had taken place in the oil, which had been used in the system for over eighteen months. It was found that the oil had gained in specific gravity through constant use, which was to be expected, as the oil in passing through the bearings had had some of its more volatile constituents driven off. The tests for viscosity showed that the used oil had a higher value than the new, thus demonstrating that as the oil is used over and over again in

the oiling system, it actually gains in body, provided, of course, that the entrained water is entirely removed by the filter. It will be noticed that the new oil has a slightly lower coefficient of friction on low bearing pressures, while the purified oil shows a lower value on higher ones. This is due to the fact that the old oil has more body and is thus better able to maintain a lubricating film when subjected to higher pressures. The difference between the two curves, however, is so slight that for all practical purposes properly filtered oil is as good a lubricant as new. A set of curves to show the difference between the temperature of the bearing and the room were practically superimposed, and in no case was the variation more than a few degrees.—"**Mechanical World**"

OIL ENGINES.

HIGH-POWER DIESEL ENGINES.

We publish elsewhere this week (June 12, 1914) extracts from a paper on "Diesel Engines," which was read by Mr. James Richardson. B.Sc., before the Junior Institution of Engineers some time ago. It is one of the most practical papers that has been read on the subject, based as it is largely on the actual experience of the author in Diesel engine construction. But it is of great length, and in order to save the time of those who are too busy to read it right through, we propose to deal briefly with some of the points raised. The author states as his opinion at the start that the marine Diesel engine has not fulfilled the expectations of the early enthusiasts, for the reasons that designs were based upon pure theory without the necessary scientific experimental work in advancing from one size of cylinder to a bigger one, and that it was assumed that the conditions applying to the construction of land engines would apply equally well to the construction of marine engines. He does admit, however, that entire success has been achieved by those firms who were primarily marine engineers, who have been conservative in increasing cylinder diameter, who have made no attempt to cut weight, and who have stuck to the four-cycle. Though he gives no names, his remarks clearly indicate two of the firms referred to, and we have obtained from them—Messrs. Burmeister and Wain, of Copenhagen, and the Nederlandsche Fabriek, of Amsterdam—a table showing the progressive increases in diameter of cylinder made by them during the last few years.

The author then proceeds to consider future possibilties, but in this he appears to be of opinion that the four-cycle engine has reached the limits of its success as he rules it out, and confines himself to the two-cycle on the plea that "the power of the four-stroke cycle engine is limited by the difficulties of dealing with the exhaust unless auxiliary exhaust ports be introduced." These auxiliary exhaust ports, he points out, would, while overcoming the difficulties with the exhaust valves, lead to a reduction in the mean effective pressure on the expansion stroke by early opening and on the compression stroke by late closing. The latter objection could, however, be overcome by putting the admission air under a slight pressure, and we venture to think that even with the trifling loss on the expansion stroke, a forced induction, auxiliary exhaust port, four-cycle engine should maintain its present position *vis à-vis* the two-cycle. The author admits in the next line that the gain in weight and space occupied with the two-cycle is not great, and that even the small saving is neutralized by the greater fuel consumption; and his real claim is justly founded on the fact that the two-cycle engine gives the greatest mean effective pressure per revolution.

Date.	No. of cyls.	Dia. mm.	Stroke. mm.	Revs.	I.H.P.	I.H.P. per cylinder.
		Burmeister and Wain.				
1911	8	530	730	145	1,250	156
1912	8	590	800	125	1,500	187
1913	6	740	1100	100	2,000	333
		Nederlandsche Fabriek.				
1909	4	320	420	235	190	47
1910	6	400	600	150	450	75
1912	6	560	1,000	125	1,100	183

A condition with regard to the speed of revolution of the Diesel engine which is very generally overlooked is involved in the statement that "the accuracy of workmanship and the excellence of materials required by those parts subjected to pressure and to temperature make it possible economically to run the oil engine at a relatively high normal speed of revolution." We are not at all sure that we agree with the author in his suggestion, which comes a little later for raising the mechanical efficiency of a Diesel engine by dividing up the fuel injection between two or more fuel valves opening at different periods of the stroke. He suggests that the valves which open after the preliminary ignition charge has been injected would require a lower pressure of air for the injection of the fuel, and that this would result in a reduction in the size of the compressor and the power required to drive it. This reduction would, however, we believe, be so trifling in practice as not to be worth the expense of the extra valves with their driving gear, simple though the latter might be. The figures given by the author in reference to the maximum load on the main bearings of a steam engine as compared with the corresponding figures from an oil engine are very significant, especially with regard to the rate of change, in their relation to the strength of the crank shaft, framing, and bed plate. A very important point is also brought out in the diagrams showing the forces acting on the guide, which in an oil engine are reversed and not constant, as with the steam engine; this, again, is an item not generally realized. The portion of the paper dealing with the engine framing is especially interesting, and the importance of keeping the load as near the center of the shaft as possible and of relieving the cylinder altogether of longitudinal stresses is clearly demonstrated.

An interesting portion of the paper is, too, that which deals with cylinder castings and the various forms they may take and the stresses they have to withstand. The author is in favor of the jacket, liner, and cover being made as three separate units, even though this arrangement involves a somewhat big mass of metal at the top of the combustion chamber, which is difficult to cool. He proposes, however, to overcome this difficulty by means of a novel design of cover, in which the load is taken on a steel plate bolted down to the cylinder flange in the usual way, whilst on the underside of this plate and spigoted into the bore of the cylinder is a cast-iron water container, as shown by an illustration in the paper. By means of the spigot the combustion chamber is carried down well below the mass of metal formed by the junction of the liner with the cylinder, and so could be completely water jacketed, and the author claims that the construction is simpler and that the water spaces are more accessible. We are afraid that we can hardly agree that the form of construction is simpler than an ordinary cast-iron cover *with the same number of valves*

in it, and we cannot believe that it would be an easy job to make a good joint for the valve cage between the steel plate, which is comparatively cool, and the cast iron, which is subject to the full explosion temperature on one side and water on the other. The author apparently only suggests the plan for engines with port scavenging—that is, with only the fuel valve in the cover—and he no doubt recognizes that it would be infinitely more difficult if there were two or three valves. It appears to us that the only way in which these joints could be made satisfactorily would be to cast a boss up from the bottom part to a height equal to the sides, and to machine this face flush right across; the steel plate would then make the water joint on the outer edge of the top of the boss. It would be provided with a hole round the central part of the boss, through which the valve could be jointed on to the face of the boss clear altogether of the steel plate. One of the objects aimed at by the author could be achieved by simply putting a more or less shallow spigot on the underside of a cover of ordinary form.

What would have been the most valuable portion of the paper but for one omission is that which deals with the materials of which cylinders and liners should be made. Not only are the conditions which such materials have to fulfil given very clearly, but their constituents are hinted at, and the author shows in the form of a table the serious effects of "growth" in cast iron of unsuitable mixture and the reduction in "growth" when cast iron of a suitable mixture is used. The, perhaps natural, omission to give away the composition of this particular mixture goes a long way to detract from the value of the rest of the information, though at this we have undoubtedly no right to cavil. A lot of useful information follows on the subject of compressors, scavenging pumps, starting, etc., and we are glad to note that preliminary warming of the cylinders is recommended before starting up, as tending both to facilitate starting and to relieve the cylinders of excessive temperature variations. We have only space here to touch upon so few of the many interesting points dealt with by the author that we would recommend those who wish for fuller information to read through the paper itself.—"The Engineer."

The article mentioned above is a very complete discussion of the details of design of the Diesel engine for marine purposes.

MOTOR SHIP *ARUM*.

"The Engineer," May 27, 1914.

General description of Polar Diesel Engine and installation in vessel. This represents one of the latest installation of Diesel engine for the merchant marine. Each set of engines has four cylinders, 410 mm. in diameter, 860 mm. stroke; H.P., 675 at 123 revolutions per minute. The vessel has a carrying capacity of 5,000 tons and a speed of 10½ knots.

DEVELOPMENT OF INTERNAL-COMBUSTION ENGINES FOR MARINE PURPOSES.*

By M. Drosne, of Messrs. Schneider and Co., Paris.

Messrs. Schneider and Co. have for some years specialized in the construction of oil engines working on the Diesel principle. They concentrated their efforts at first on four-stroke cycle engines specially designed for submarines for the French Navy or for foreign navies, but they very soon found that the two-stroke cycle type might be of great use for en-

*Paper read before the Institution of Mechanical Engineers at Paris, July 8, 1914.

gines of medium and of high power, both as regards reduction in weight and bulk, as well as for improvement in cyclic regularity. They therefore had no hesitation in studying and constructing that type of engine, together with the four-stroke cycle one. Being, on the other hand, aware of the fact that it was not advisable to start on this new line without precise data on the advantages of the two-stroke cycle, derived from their own experience, they faced the heavy cost of erecting a couple of two-stroke cycle engines at the works for trial purposes. These were vertical and each with a single cylinder. One had a stroke of 1 m. (3 feet 3.37 inches), and developed 1,200 H.P. at 150 revolutions per minute. The other had a stroke of 0.46 m. (1 foot 6.11 inches), and developed 300 horsepower at 400 revolutions per minute. These engines were to give an idea of the difficulties in regulating and running engines of large size or at high speed, so that means could be found to remedy any defects that might arise. The results enabled the constructors to start with confidence on the difficult solution of the problem relating to high-speed two-stroke cycle light engines for submarines, and placed them in the foremost technical position to solve the problem of the use of large oil engines for ordinary vessels. The experiments took place over a period of two years.

The two-stroke cycle engines—like the four-stroke cycle—are mostly light engines, of relatively high horsepower, built for marine work. On the other hand, the constructors did not lose sight of the development of heavy slow-speed engines (four-stroke cycle or two-stroke cycle) for cargo boats, or of horizontal double-acting engines of high horsepower for land purposes. Their great experience in the construction of engines for land and sea placed them in such a position that they could safely set to work in executing their new designs, and today they are able to deal with all the intricacies of Diesel engines either of the land or marine type, two-stroke cycle or four-stroke cycle, vertical or horizontal, and single or double-acting. These engines have been highly successful, due to the excellence of construction and the materials used, the original design of the mechanism, and the care taken in perfecting them.

The following engines constructed at their works are worthy of note:

(*a*) Eight engines of 360 horsepower each, four-stroke cycle, with eight cylinders, stroke 0.28 m. (11.02 inches), 400 revolutions per minute, for submarines of the *Laubeuf* type.

(*b*) Two engines of 700 horsepower each, four-stroke cycle, with four cylinders, stroke 0.48 m. (18.9 inches), 300 revolutions per minute, and two motors of 150 horsepower, four-stroke cycle, with four cylinders, 360 revolutions per minute, representing the main and auxiliary engines of the French submarine *Admiral Bourgois*.

(*c*) Two engines of 900 horsepower each, two-stroke cycle, with four cylinders, stroke 0.56 m. (22.05 inches), 230 revolutions per minute, for the cargo boat *France*, belonging to the Société des Navires Mixtes, of Rouen.

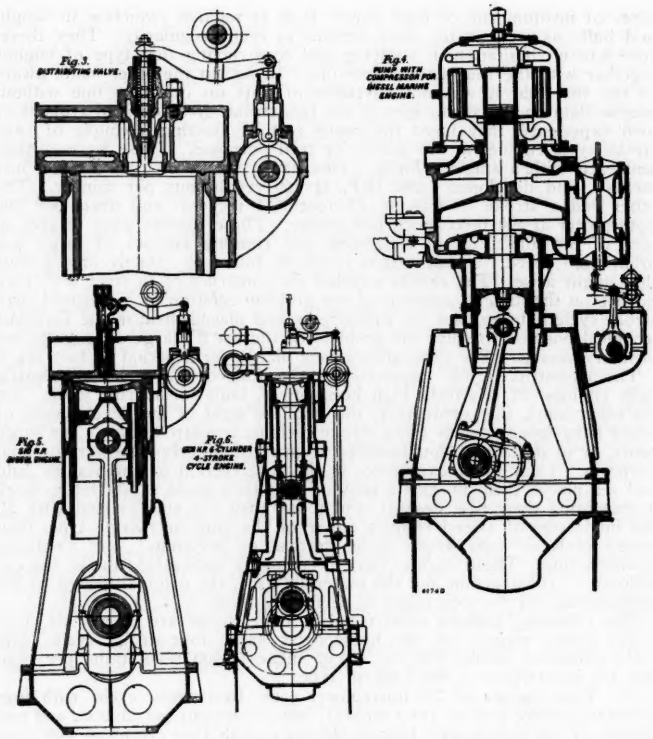
(*d*) Two engines of 2,400 horsepower each, two-stroke cycle, with eight cylinders, stroke 0.47 m. (18.51 inches), 350 revolutions per minute, for the French submarine *Nereide*.

(*e*) Six engines of 650 horsepower each, two-stroke cycle, with six cylinders, stroke 0.36 m. (14.17 inches), 400 revolutions per minute, for a French submarine.

(*f*) Eight engines of 1,100 horsepower each, two-stroke cycle, with eight cylinders, stroke 0.37 m. (14.57 inches), 400 revolutions per minute, for submarines of the *Laubeuf* type.

(*g*) One engine for an electric generating set of 225–250 horsepower, two-stroke cycle, with three cylinders, stroke 0.36 m. (14.17 inches), 300 revolutions per minute.

It must be remarked that the submarines of the *Laubeuf* type come from Messrs. Schneider & Co.'s naval works. Other engines in course of design or of construction may be mentioned:



Four engines of 510 horsepower, four-stroke cycle, for submarines; one engine of 1,500 horsepower for a cargo boat; one horizontal tandem engine, double-acting, four-stroke cycle, of 2,200–2,600 horsepower, for an electric generating station; and two-stroke cycle engines of 1,100 horsepower for submarines.

DESCRIPTION OF THE ENGINES.

All the engines for submarines, whether four-stroke cycle or two-stroke cycle, are extra light. They are vertical, single-acting, with trunk pistons. The bedplates and frames are of cast steel; the cylinders, which are either separate or cast with the frames, are of cast iron or cast steel with cast-iron liners. The cylinder-cover is of cast steel and carries (for four-stroke cycle engines) the inlet valve, the exhaust valve, the injection valve for fuel, and starting valve. For two-stroke cycle engines the air and exhaust valves are replaced by scavenging valves.

The crank and cam shafts are of medium hard steel, which is tempered and annealed, and all the parts subjected to hard wear, such as cams, rollers, valves, pins, compressor valves, etc., are in special steel. The air inlet and exhaust pipes (the latter having water jackets) are of sheet steel. All parts exposed to heat, such as the cylinders, cylinder covers, exhaust-

valve seats and exhaust pipes, are water jacketed. For the four-stroke and the two-stroke engines of large size the pistons are cooled by oil circulation. The crank pins and crank-shaft bearings, the cylinders, and other main working parts have forced lubrication. The air compressors, and for the two-stroke engines the air compressors and scavenger pumps (whether separate or forming part of the engine), are worked directly off the crank shaft, which in many cases also works the oil pumps for lubricating and cooling, as well as the pump for the water circulation. All these devices are practically the same for heavy engines, except that for the latter the bed plates, frames and cylinders are of cast iron, and the pistons are provided with rods and crossheads in engines of larger size.

IMPROVEMENTS IN WORKING PARTS.

Starting the Maneuvering Gear.—This has been applied to all the latest engines with a view to make starting and reversing as easy and as quick as possible. There are two cams for operating each valve on the main cam shaft, one for ahead and the other for astern running. The rocking levers are, however, also controlled by cams fixed to a maneuvering cam shaft, and these cams are adjustable, so that in certain positions the rocking levers are thrown completely out of gear with the main cams. Thus one can see that by making adjustments to the cams on the maneuvering cam shaft certain valve levers will be thrown out of gear, whereas others will continue to bear on their main cams, so that according to the distribution required it is possible, when starting, to connect all the cylinders to the compressed-air supply, and then by adjusting the maneuvering cams to cut the air off from one or more of the cylinders and feed one or more with fuel as required. The adjustments to the maneuvering cams is made by revolving the cam shaft, and one complete revolution of the shaft, worked by hand through a reducing gear, or by a servo-motor, is sufficient to start the engine. In the position corresponding to "stop," all valve-lever rollers are free, so that in order to change from ahead to astern drive all that is needed is to move the maneuvering cam shaft to the "stop" position, and then to move the main cam shaft longitudinally so as to place the "astern" cams under the valve-lever rollers, and then start the engine as explained above. This operation, which only takes 10 to 15 seconds, is made by successively rotating two small hand wheels placed side by side one after the other. A safety device prevents the main cam shaft moving longitudinally until the other cam shaft is moved to the "stop" position. The whole arrangement is remarkably safe.

Valves.—The exhaust, air-inlet, and starting-valves (Fig. 3) are of the ordinary type, except that they are provided with a special device to prevent their falling into the cylinders if their rods break. The fuel valves are either of the ordinary type—that is, direct-acting straight needles passing through a stuffing box—or of the Swedish type, balanced and worked by rotation.

Fig. 5.—This figure shows the cross section of a cylinder belonging to a four-stroke cycle engine, of eight cylinders and 510 horsepower. The fuel-valve casing is fitted at the bottom with a ball pulverizer and a multiple-hole diffuser. The ball pulverizer distributes the fuel in a very uniform manner with the air that is injected, though it offers but little resistance to the passage of that air owing to the balls being round. On the other hand, the multiple-hole diffuser allows the mixture to be sent in the required direction so as to distribute it evenly in the compression chamber, thus preventing it from being injected on to any one part that might get injured.

Fuel Pumps.—One pump is provided for each cylinder. The plungers are specially constructed so as to render them perfectly tight. Each oil pump is regulated by varying the amount of lift of its suction valve, and the special feature of the gear for giving this variation is as follows:

(1) Hand regulation; (2) Regulation from the maneuvering cam shaft; (3) Regulation by over speed. The hand regulator, which works on a quadrant, serves to regulate the speed or load on the engine. The regulation from the maneuvering shaft comes into play when starting ahead or astern, so that the pumps begin to work at the right moment only. Lastly, the speed-limit device acts so as to prevent racing.

Air Compressors.—The air compressors, either independent or combined with the scavenger pumps in the two-stroke cycle engines, Fig. 4, are three-stage compressors and are worked direct off the crank shaft. Their valves, which are of special steel, extra light and with short lift, are designed so as to give large openings. Their coolers, which are multitubular or of the coiled single-tube type, are fitted with large water jackets, and ensure the most efficacious cooling.

Scavenging Pumps.—According to the speed, the scavenging pumps, which are worked off the crank shaft, are provided with Hoerbiger valves or cylindrical slide valves. Fig. 4 shows a cross section of a pump with cylindrical slide valves, and combined with its compressor, of which it forms the low and intermediate-pressure part. The slide valves are driven by eccentrics fixed on the main cam shaft. A sliding sleeve with feather enables the cam shaft to move longitudinally for ahead or astern drive without affecting these eccentrics.

Oil-Cooled Pistons.—The pistons are in two parts, joined together by long bolts, in which tubes carrying the cooling oil work telescopically (Fig. 5). The piston head carries segments in cast iron or steel which bear lightly against the central part of the body of the piston. The telescopic tubes are provided at the bottom with a swivel joint, leaving them free to move in any direction, and maintaining a proper oil-tightness. The hot oil is returned from the piston to a filter, whence it is pumped by a special pump through a tubular cooler and back into the pistons.

Forced Lubrication. Splash Guards.—The bearings of the crank shafts and of the connecting rods have forced lubrication. This is an excellent arrangement for efficient lubrication, but the splashing of oil by the cranks is undesirable for the following reason: The oil thrown on to the cylinder walls is sucked past the piston, which causes waste, and its partial combustion causes a smoky exhaust. These defects are now got rid of by means of special splash guards. These are very efficacious.

Fig. 6 shows a section through one of the six cylinders of a 1,500-horsepower engine for a cargo boat, of the four-stroke cycle type, and of low speed, which is now being designed. The pistons are provided with rods and crossheads, and they are cooled by water circulation. The frames joining the cylinders to the bedplate are made in two halves, bolted together and arranged so that one half can be easily removed, to allow the connecting rod, piston, and crosshead to be taken out. The same arrangements apply to this motor as have been already described above.—"Engineering."

THE CHARGING OF TWO-CYCLE INTERNAL-COMBUSTION ENGINES.*

By B. Hopkinson, M. Inst. C.E., F.R.S.

The perforance of two-cycle internal-combustion engines is determined very largely by the efficiency or otherwise of the process of charging. In the course of less than one-fourth of a revolution the products of combustion resulting from the previous explosion have to be replaced as far as possible by the fresh charge of air, or of gas and air, which is blown

*Paper read at the joint meeting of the Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland, and the North-East Coast Institution of Engineers and Shipbuilders, at Newcastle-on-Tyne, July 8, 1914.

in through the inlet valves and drives before it through the open exhaust ports the exhaust gases. Inevitably some mixing occurs, and some of the fresh charge, or of the scavenging air, passes away to the exhaust, and is wasted. On the amount of this waste depends very largely the performance of the engine. Its economy suffers to the extent of the waste of fuel. Its weight and cost are affected by the size of the charging pumps, which must be big enough to deliver the whole charge of gas and air, including that which is wasted. The imperfection of the charging process is probably in large measure responsible for the fact that the two-cycle engine, in spite of the obvious advantage of double the number of working strokes, has not hitherto competed successfully in small sizes with the four-cycle type, and even in large sizes has achieved only moderate success.

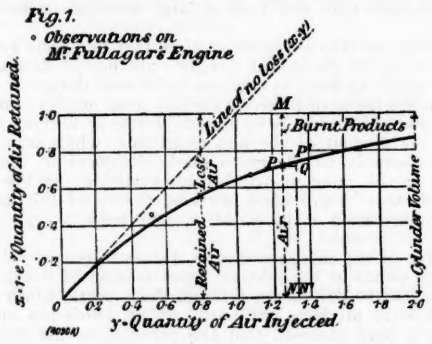
In considering recently the designs of certain two-cycle gas engines, the author was struck by the almost complete absence of data of general application on which to base, in the case of a new design, a calculation of the size of pumps required to give a certain mean pressure and a prediction of the economy which may be expected. Little or nothing has been published as to the amount of the loss to exhaust which occurs in existing engines, and there is no theory to guide designers in the use of such data as exist on this point or may become available. In the present paper an attempt is made to provide a working theory of this kind, some experimental confirmation is given of it, and methods are suggested for getting more information.

In the course of the charging process, for each unit of volume of air or mixture which enters at the inlet an equal volume of the gas near to the exhaust ports will be driven out through those ports, which gas will consist partly of burnt products and partly of air which has mixed with the products. It is here assumed that the pressure in the cylinders during the admission period is that of the atmosphere; the effect of the disturbance of this pressure by throttling at the exhaust ports, and by the inertia of the gases in the exhaust pipe will be considered later. Denote by z the proportion of air by volume contained in the exhaust gases. This will be the same as the proportion which is contained in the cylinder contents near to the exhaust ports at any state of the charging. For this purpose z is not the volumetric proportion determined by an ordinary analysis; it is the volume, reckoned at atmospheric pressure and at the temperature of the air as it comes in, contained in a cubic foot of the cylinder volume; the balance $1-z$ consists of burnt products from the previous explosion, whose volume is, for this purpose, reckoned at the temperature of those products before charging began. Obviously z will increase from zero as charging goes on, and will approach, but never reach, the value unity; at first, when very little air has been put in, the exhaust gases contain no air; when a large quantity has been blown through, the exhaust is almost pure air. The total amount of air lost in charging will be equal to the volume delivered (denoted by z) multiplied by the average value of z, and is readily calculable if this quantity is known at every stage. The amount of air retained in the cylinder is equal to y minus the loss; this will be denoted by x.

Two cases admit of very simple treatment. The first is the ideal case of perfect stratification. The air simply drives the burnt gases before it without mixing with them at all, and there is no loss until the amount of air exceeds the cylinder volume. It is quite certain that this condition is never even approached in practice. Probably the first two-cycle engine ever built, that made by Dr. Dugald Clerk, in 1880, came nearer to attaining this ideal condition than any which has been made since. Dr. Clerk, who thoroughly appreciated the necessity of getting as much stratification as possible, used a very long conical combustion chamber. Even so, there must have been a good deal of mixing, and in modern high-compression engines (the compression ratio in the Clerk engine was 3) such a construction is impossible.

The second case represents much more nearly what actually happens. Suppose that instead of complete stratification there is no stratification at all—suppose the mixing so complete that the cylinder contents are at every instant of uniform composition throughout. Here again it is possible to calculate the proportion lost up to any stage with complete certainty and accuracy. The quantity z now represents not only the proportion of air in the gas which is going into the exhaust at any stage, but also the proportion then present in the cylinder as a whole. It is convenient in these calculations to take as the unit of volume the whole volume of the cylinder, and x the volume of air which has been retained in the cylinder then represents also the proportion of air in the whole cylinder contents, so

Fig. 1.



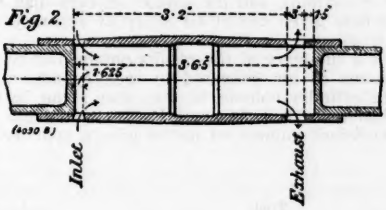
in the case now under consideration $z = x$. In Fig. 1 x is plotted against y, the amount (reckoned in cylinder volumes) of air which has been injected. When an amount O N has been injected, the air present in the cylinder P N, the remainder P M being burnt products. The effect of adding the further dose of air N N^1 is to expel at the exhaust the quantity of air $\frac{P\ N}{M\ N} \times N\ N^1$. The balance remains in the cylinder, increasing the quantity of air there by $P^1Q = \frac{P\ M}{M\ N} \times N\ N^1$. So the curve can be constructed step by step. It is the well-known exponential curve whose slope at any point is equal to the ordinate P M. The relation between x and y (of course, easily obtained mathematically) is $x = 1 - e^{-y}$.

In many engines now in use the mixing is probably fairly complete, and the simple formula just given represents fairly accurately what occurs. Such are short-stroke Diesel engines with valves in the cylinder cover, and probably also the double-ported engines having the inlet ports opposite the exhaust ports and a deflector plate on the piston. In engines having relatively longer cylinders, such as the Oechelhaüser, there is some stratification of the cylinder contents; but even here the effects of stratification are probably not very great. They are of the nature of a correction, and before discussing this correction along with others, the necessity of which will appear later, it will be convenient to compare the simple formula with results actually obtained from an engine in the course of some recent trials conducted by the author for the Fullagar Engine, Limited, and then to give some illustrations of its application to other papers.

TESTS ON MR. FULLAGAR'S ENGINE.

The engine in question was built to the designs of Mr. H. F. Fullagar. It represents an important development in large-power gas engines, and has several features of great interest, but, as Mr. Fullagar will be de-

scribing it himself, it is only necessary to give here such details as bear on the subject of this paper. It has four vertical cylinders of the Oechelhaüser type, coupled together in pairs, the upper piston of one being coupled by diagonal rods to the lower piston of its neighbor, in the manner invented by Mr. Fullagar. The leading dimensions of each cylinder are given in Fig. 2. The air ports (there is only one set of admission ports) communicate with a large receiver, to which air is delivered by an electrically-driven fan. Coal gas was used in these trials, and was admitted by a piston valve at the center of the cylinder. The valve was opened 5 degrees of crank angle before the exhaust ports closed, and remained open for 36 degrees crank angle. The coal gas was delivered at high pressure by a reciprocating pump.



The verification of the formula above given required the accurate measurement (1) of the total quantity of air delivered to the engine per minute, and (2) of the proportion of that air retained in the cylinder.

1. *Quantity of Air.*—A diaphragm with a circular hole was inserted in the air-delivery pipe, between the fan and the engine, and the drop of pressure measured by means of a water gage. The diameter of the air pipe was 18 inches, that of the hole in the diaphragm 9 inches. The current of air through the diaphragm was nearly uniform, the pulsations caused by the engine being nearly damped out by the large air receiver. The velocity of the air through the hole was calculated according to the usual formula, assuming 0.62 as the coefficient of discharge. The coal gas was also metered, and the quantity of coal gas used, together with an analysis of the exhaust gases, gave an independent measure of the amount of air used. The quantity of air delivered to the engine was probably determined correct within 3 per cent.

2. *Proportion of Air Retained.*—For determining this samples were taken of the contents of all four cylinders, and analyzed. The average proportion of carbon determined in the samples was compared with the proportion in a sample of the exhaust gas taken simultaneously. The ratio of the two carbon contents is equal to the ratio of the total air delivered to the air retained in the cylinder, $\frac{y}{x}$ in our notation.

For the purpose of collecting the samples of the cylinder contents a pipe of very small bore was screwed into a hole drilled in the sparking plug. The other end of the hole was closed with a nipple having a small hole in it. The pipe communicated with the sampling vessel, into which it delivered the gas slowly, a small quantity coming in at each explosion. The result of this procedure is that the sample consists partly of a mixture of unburnt gas and air blown through the pipe during the compression stroke, and partly of burnt gases which come through during the expansion stroke. Usually the proportion of burnt to unburnt was about 2 to 1. As the coal-gas admission valve is opposite the sampling hole, both being at the middle of the length of the cylinder, the tendency of the method is to collect samples which are a little too rich in coal gas. But it is believed that the error so caused is not large. The greater part of

the sample comes through while the pistons are near the in-center, by which time any stratification of the coal gas will in large measure have disappeared, and will, moreover, be of less importance because of the compression of the cylinder contents.

Samples were taken from all four cylinders simultaneously, and after absorbing the CO_2 the combustion of the residue was completed over palladium, and the further yield of CO_2 obtained. The total CO_2 gave the proportion of coal gas to air in the cylinder contents. A simultaneous analysis of the exhaust gases gave the proportion of coal gas to air delivered to the engines. A check was obtained by estimating the oxygen in the exhaust and in the cylinder contents. The analyses were made for the Fullagar Engine, Limited, by Dr. Mechie and Mr. Hill, of the Wallsend Laboratories. Great care was taken by these gentlemen to eliminate all errors in the estimations, and the author believes that, thanks to their labor, the figures now given are of an order of accuracy rarely attained in a commercial trial.

The following is a summary of the results obtained in two trials, in one of which the volume of air delivered to each cylinder per stroke was about equal to the cylinder volume, in the other about half. In the first case the engine had to be run slow, as the fan would not at the normal speed deliver a sufficient volume of air to give a cylinder-full per revolution:

Trial.	Ia.	Ib.	II.
Speed, revolutions per minute	200	200	250
Air per cylinder per revolution (by diaphragm), cubic feet	2.70	2.70	1.42
Air per cylinder per revolution (by gas-meter and exhaust analysis), cubic feet	2.86	2.86	1.38
Coal gas per cylinder per revolution (by meter), cubic feet	0.189	0.182	0.163
$\frac{\text{Air}}{\text{Coal-gas}}$ delivered to engine (exhaust analysis)	15.1	15.7	8.45
$\frac{\text{Air}}{\text{Coal-gas}}$ in cylinder contents (analysis, mean of four cylinders)	9.4	9.45	7.35
Air retained, per cylinder per revolution, cubic feet	1.78	1.72	1.20

The volume of the cylinder when the pistons are at the out-center is 2.75 cubic feet. When the inlet ports are just closed it is 2.50 cubic feet. Having regard to the dwell of the pistons near the out-center, the mean volume during the period of injection will be nearer to the former figure; take it as 2.65 cubic feet. Dividing this volume into the volumes of air given on lines 3 and 7 of the above table we get the value of y and x. They are tabulated in the following table, together with the corresponding values of x calculated from the formula.

.....	Ia.	Ib.	II.
y = air delivered per cubic foot of cylinder volume	1.08	1.08	0.62
x = air retained per cubic foot of cylinder volume	0.67	0.65	0.45
Calculated value of x $(= 1 - \epsilon - y)$	0.66	0.66	0.405
$y - x$ (measured)	0.41	0.43	0.07
$y - x$ (calculated)	0.42	0.42	0.115
Percentage of air lost to exhaust (measured)	38	40	13.5
Percentage of air lost to exhaust (calculated)	39	39	22

It will be seen that there is rough agreement between the calculated and measured figures, sufficient at any rate to justify the use of a simple supposition of complete mixing as a first approximation to what occurs. On the other hand, the deviation with the smaller amount of air is too great to be ascribed to errors of observation. The observed loss of air is only

about two-thirds of the calculated loss. This shows that there are disturbing factors which must be taken into account as corrections to the simple theory. In trials IA. and IB. these connections apparently neutralize each other, producing, as it happens, almost exact agreement. Before dealing with these corrections, it will be convenient to give one or two simple illustrations of the application of the theory to practical cases.

(*a*) Diesel engine, stroke equal to bore, or slightly greater; inlet valves in cylinder cover. This is a case in which the mixing will be nearly complete. Suppose that the volume of the air pump is 1¼ times the total cylinder volume (including clearance space). The volume of air delivered, reckoned at the temperature of delivery, will be approximately that of the pump, the rise of temperature due to the pumping work compensating for the volumetric inefficiency of the pump. Hence $y = 1.25$ and the volume of air retained (P N in Fig. 1) is $x = 1 - e^{-1.25} = 0.71$. The volume wasted ($y - x$) is 0.54, or 43 per cent. of the amount pumped. The cylinder contents consist of a mixture of 0.71 air at 40 degrees to 50 degrees C. (temperature in air-delivery pipe) and 0.29 of burnt products at perhaps 500 degrees C. The scavenging is far from complete, and the charge would be rather hot and the flame temperature correspondingly high, necessitating a low mean pressure in order to avoid overheating. It may be added that no substantial improvement can be effected in this respect except by the use of excessive quantities of air. For instance, it will be seen from the diagram that to reduce the amount of burnt products left in the cylinder to 15 per cent. the air pump must be nearly twice as big as the cylinder.

(*b*) Gas engine, with separate gas and air pumps, using producer gas. In such an engine the pumps and admission valves or ports would be arranged so that as far as possible the air goes in first, the gas following it. Thus in the Oechelhaüser the air ports open first, and a large part of the air is discharged through them before the gas ports open. Then the gas comes in, mixing with the remainder of the air. The amount of air coming in with the gas in any case can be calculated roughly beforehand from the size of receivers and the size and position of gas and air ports; but such calculations are apt to be much upset by the exhaust back pressure, whose efforts are difficult to allow for, and will vary in different cases according to the length of the exhaust pipe. For purposes of illustration, we will assume that at full load the volume of air passing the air ports before the gas ports open is half the cylinder volume; and that this is followed by quarter cylinder volume of gas and the same quantity of air, and that no air enters after the gas ports are closed.*

The volume of mixed gas and air is half the cylinder volume. Hence $y = ½$, and the amount of mixture retained in the cylinder per cubic foot of its volume is $x = 1 - e^{-0.5} = 0.394$. The proportion of the pumped gas which is retained and burnt is $\frac{x}{y} = 0.79$, and the balance (21 per cent.) is wasted to exhaust. Assuming the engine to have a compression ratio of 6.5 (ratio of cylinder volumes at out and in-center), it would give an indicated efficiency on the basis of the gas actually burnt of 0.37 or 0.38, say 0.375. The quantity of gas retained and burnt per cubic foot of stroke volume is $0.79 \times 0.25 \times \frac{6.5}{5.5} = 0.233$ cubic foot. If the gas has a lower calorific value of 140 British thermal units per cubic foot at atmospheric pressure and at the temperature in the receiver, the indicated mean pressure will be $0.375 \times \frac{0.233 \times 140 \times 778}{144} = 66$ pounds per square inch, which

*With a perfectly free exhaust, this distribution of air and gas is possible in the ordinary design of the Oechelhaüser engine; but the author is of opinion from data in his possession that in ordinary practice the distribution is not so good. Cards taken from the receivers in one case, which is probably typical of many, show that the exhaust pressure had not fallen to atmosphere when the air ports opened, so that the air was held up, and more of it went in along with the gas than is here assumed.

is a little above the normal figure for an engine of this type. Allowing a mechanical efficiency of 83 per cent., the practical efficiency (ratio of brake power to the lower heat value of the whole of the gas pumped) will be $0.83 \times 0.79 \times 0.375 = 0.246$, equivalent to about 10,400 British thermal units per brake horsepower hour.

In practice two-cycle gas engines do a little better than this, though at the high mean pressure of 66 pounds per square inch, it is doubtful whether any of them could be relied on to produce a brake horsepower hour for much less than 10,000 thermal units. The Oechelhaüser engine with its long cylinder gets the benefit of some stratification. In the Körting the admission valve is timed so that it closes after the exhaust ports, and some of the charge is thus trapped without any possibility of getting out. On the other hand, in both cases these favorable factors are apt to be neutralized by the exhaust pressure holding up the scavenging air. But broadly speaking, and subject to corrections of this nature, which, on the whole, are small, the simple theory leads to conclusions which are in accord with practical results. It may be noted in this connection that the Fullagar engine, in which there was no waste of gas at all, showed an indicated efficiency of 0.376, and a brake efficiency of 0.30; and the latter figure would reach 0.31 if the mechanical efficiency were raised to the normal figure for these engines by the use of a more economical method of serving the engine with air.

Effects of Stratification.—In the simple theory of the charging process which has been discussed, it is assumed that at every instant during the period of admission the cylinder contents are homogeneous in composition, and that their pressure is that of the atmosphere. In fact, there is in all engines some stratification of the cylinder contents, the portions near the exhaust ports being poorer in air and richer in burnt products than the average. There is also in all cases some throttling in the exhaust ports and exhaust pipe, and inertia effects in the exhause pipe, in consequence of which the pressure in the cylinder varies during the admission period. The effects of these two factors will now be considered, beginning with stratification. Suppose that y represents, as before, the volume of air which has been delivered through the inlet ports at any stage, and x the volume which has been retained in the cylinder, $y - x$ having been wasted through the exhaust ports. These volumes are reckoned in terms of the total cylinder volume taken as unity, and x is therefore the average proportion of air (by volume) in the cylinder contents. These contents are now, however, not of uniform composition, but near the inlet ports they are richer in air than the average, and near the exhaust ports poorer. Thus a cubic inch of air delivered through the inlet now displaces and drives through the exhaust a cubic inch of gas containing a proportion z of air, where z is less than x. The full discussion of the relation between z and x—that is, of the amount of stratification—is beyond the scope of this paper; it will suffice to state here that there are good *à priori* grounds for the supposition that in practical cases it is given by an expression of the form:

$$z = x\ [1 - \lambda(1 - x)]$$

where λ is a constant depending on the engine (proportions of cylinder, size and shape of ports, &c.). It will be seen that this formula satisfies two necessary conditions: the one that at the beginning of injection the exhaust shall contain no air ($z = 0$ when $x = 0$), the other that when a large quantity of air has been blown in, so that the burnt products have been nearly all cleared out, the exhaust shall be practically pure air ($z = 1$ when $x = 1$).

The constant λ, which is characteristic of the engine as regards stratification, I propose to call the "stratification constant." The greater its value the greater is the amount of stratification; and when $\lambda = 0$ there is

no stratification, for then $z = x$; that is, the proportion of air near the exhaust ports is equal to the average proportion throughout the cylinder.

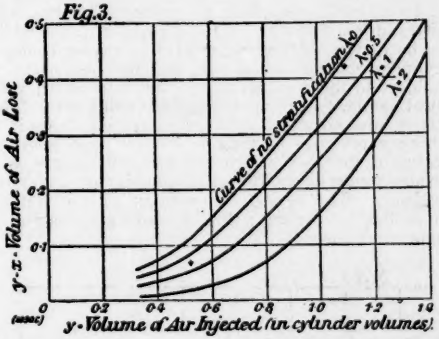
Once the proportion of air near the exhaust ports (z) is known in terms of the average composition (x), the relation between the quantity of air retained (also x) and the total quantity rejected (y) can be obtained with mathematical certainty. For the relation between z and x given above, it takes the form:

$$x = \frac{1 - e^{-(1+\lambda)y}}{1 + \lambda e^{-(1+\lambda)y}}.$$

This formula applies to such amounts of stratification as are likely to occur in practice, for which λ will not usually exceed 1. For larger values of λ the expression for z in terms of x obviously ceases to be accurate, since it would take a negative value unless x is nearly equal to 1. The more accurate relation between x and z, to which the simple equation given above is an approximation, leads to a somewhat more complicated formula for x in terms of y, which it is unnecessary to give here, as it is not required in any practical case.

In Fig. 3 are plotted the curves of loss ($y - z$) calculated from this formula for various values of λ. If this constant is known for the type of engine under consideration, the corresponding curve gives (subject to any correction for the effects of exhaust back pressure) the amount of air wasted out of any given quantity injected. It is to be noted that in most cases λ is not much greater than unity, and a comparatively rough guess at its value, based on experience with similar engines, will give results good enough for practical purposes.

Fig. 3.



The points determined from the tests on Mr. Fullagar's engine are noted on the same sheet, from which it will be seen that the lower point falls between the curves corresponding to $\lambda = 0.5$ and $\lambda = 1$, while the upper, as already indicated, falls near the curve $\lambda = 0$.

EXPERIMENTS WITH A WATER MODEL.

The phenomenon of stratification can be studied very conveniently by means of a model of the engine cylinder in which water is used instead of air. The model can be made to scale, of sheet iron, and is provided with an admission valve at the lower end, which can be opened and closed by hand. Through the valve the cylinder communicates with a large chamber containing water with an air space above, whose volume is equal

to or greater than that of the water. Air is pumped into the chamber until the pressure is 10 or 15 pounds per square inch. The exhaust ports at the upper end of the cylinder are permanently open, and discharge into a channel, whence a shoot leads to a tank. The cylinder is filled up to the edge of the exhaust ports with brine containing a known proportion of salt; this corresponds to burnt products. In making an experiment the valve is rapidly opened and closed by means of a handle and crank, this operation taking in an ordinary case about 1 second. The water from the chamber (which corresponds to the air in the engine) rushes through the inlet valve and displaces the brine. Samples of the contents of the cylinder and of the exhaust tank are then analyzed for their contents of salt, and from the analysis the quantity of pure water which has passed out through the exhaust along with the brine can be estimated. The experiment corresponds, in fact, with that already described as having been made on Mr. Fullagar's engine, in which simultaneous analyses were made of the cylinder contents and of the exhaust gases.

The use of water models for ascertaining the behavior of air is familiar to those who are concerned with aeronautics. The resistance of an airship, for instance, can be ascertained by towing a model in a water tank. Theory, which has been confirmed by experiments of many different kinds, shows that the motions of the two fluids will be dynamically similar if the velocities and the linear dimensions are so related in the two cases that $\frac{V L}{v}$ is the same for both, v being the viscosity. For air the value of v is about 13 times as great as it is for water. Hence, if the dimensions of the model and ship are the same, the motions will be similar if the model is towed 1/13 of the speed of the ship.

In the case of the engine cylinder the matter is more complicated, because the hot burnt products which the cylinder at first contains have greater viscosity and less density than the air which displaces them. Moreover, owing to the varying back pressure in the exhaust, changes of density occur in the cylinder contents which can have no counterpart in the water model. But subject to these points there cannot be any question that the law of dynamical similarity will apply equally to this case. That is to say, if producer gas is injected into a cylinder containing cool air (as happens if there has been a previous scavenging charge) and possessing a completely free exhaust, the loss will be precisely the same as the loss of water in the water model when the same quantity of water is injected at 1/13 of the velocity. The period of injection of the water will be 13 times as great as that of the gas; thus the whole operation can be done slowly by simple mechanism.

Fig. 4.

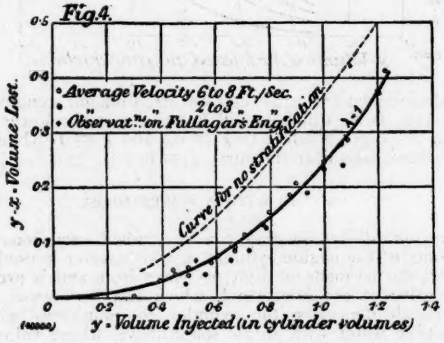
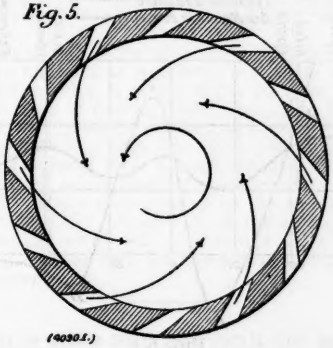


Fig. 4 shows the results of a large number of experiments made on a full-size model of Mr. Fullagar's engine. The curve is that corresponding to the formula given above for the case where $\lambda = 1$. It will be observed that within errors of observation the observed points agree with this curve. This is a satisfactory confirmation of the theory on which the formula is based. It will also be noticed that the velocity of injection varies widely in different experiments, but that there is apparently no considerable difference between high and low velocities as regards the loss to exhaust. This fact is of some importance, because it follows from it that similar variations in the viscosity of the fluid would have a like small effect.

On the same diagram are marked the two points showing the loss of air actually occurring in Mr. Fullagar's engine. It will be seen that in both cases the loss in the engine is greater than in the model, though the difference is not very great in the case of the smaller quantity of air. The differences must be due to one or both of the two factors which have been mentioned as not represented on the model; that is, the difference in viscosity and density between the air and the burnt products which it displaces, and the varying pressure in the cylinder. The effect of viscosity is certainly small; that of density may be considerable. But in the author's view it is probable that the important cause of the difference is the varying pressure, which is considered in greater detail in the next section.

Fig. 5.



It is obvious that the use of water models cannot be relied on as a means of quantitative investigation until further comparisons have been made between engines and their models, and even then the disturbing factor of exhaust pressure complicates the interpretation of the results. But the author believes that it promises to be a useful way of comparing, with little expense and trouble, the properties of different forms of cylinder and of ports and valves as regards stratification. For instance, it would appear from experiments of this kind which the author has made that a cylinder like the Oechelhaüser, whose length is perhaps three times its diameter, is much better from this point of view than a cylinder of one-third that length, such as a short-stroke engine with admission valves in the cylinder cover. In the shorter cylinder none of the many devices that the author has tried with the view of directing the motion of the incoming air have availed to produce any stratification. But in the larger cylinder it would appear that such an arrangement as is shown in Fig. 5, whereby a whirling motion is given to the air, has the effect of substantially reducing the loss.

EFFECT OF VARYING PRESSURE IN THE CYLINDER.

Both the simple theory and the discussion of the correction of that theory for stratification rest on the assumption that the pressure in the cylinder is atmospheric during the admission period. As a matter of fact, in any actual case this pressure will vary, the variations being determined partly by the throttling effect of the exhaust ports, but mainly by the inertia of the column of gas in the exhaust pipe. The surging of this column of gas causes the pressure in the exhaust pipe near the engine to rise and fall in a periodic manner, the period depending on the length of the pipe. A full discussion on the amount and nature of these variations of pressure is outside the scope of this paper, and all that will be attempted is a short consideration of their effects, in one or two simple cases, on the charging of a two-cycle engine.

It seems probable that those pressure variations which are likely to occur in practice will cause increased loss to exhaust. For instance, it may happen that the exhaust-pipe pressure is rising when the admission ports or valves are first opened, with the result that at first the injection of a cubic inch of air will not be accompanied by the discharge of an equal volume of mixed air and burnt products, but a less volume will be discharged. When at a later stage the exhaust-pipe pressure falls to atmosphere or (it may be) below atmosphere, the excess volume which had

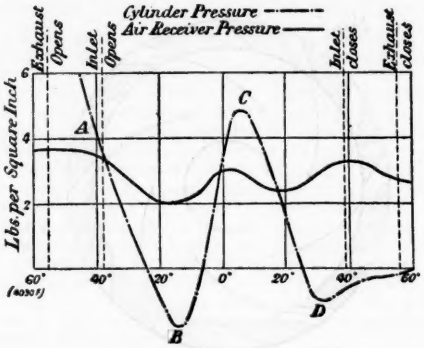


FIG. 6.

been held up in the cylinder will be discharged. The proportion of air in the gas which then goes out corresponds to the whole, or nearly the whole, amount which has been injected, and will be greater than it would have been had the exhaust come out as fast as the air went in. To take an extreme case, suppose that half of a cylinder volume of air is put in without anything going out of the exhaust ports at all. The cylinder contents will then consist of one volume of burnt products more or less thoroughly mixed with half a volume of air, the pressure of the whole being 1½ atmospheres. Now suppose that the exhaust-pipe pressure falls to 1 atmosphere. The accumulated cylinder contents now well mixed up, will at once escape. The volume of gas passing out will be half the cylinder volume, and it will consist of air and burnt products in the proportion of 1 to 2. Thus the quantity of injected air which is lost will be $1/3 \times 0.5$, or 0.17 cylinder volume. Reference to the curve, Fig. 1, will show that if the pressure had been uniform, the quantity lost (in the absence of stratification) would be 0.105. This, of course, is an extreme case, which could not arise in practice, but it shows the

tendency of a high exhaust pressure at the beginning of admission to increase the loss of air.

The actual pressure variations in the cylinder of the Fullagar engine at a speed of 250 revolutions per minute are shown in Fig. 6. It will be seen that here the surging in the exhaust pipe is of such a character as to produce a drop of pressure in the cylinder during the first part of the admission period (A to B). During this period the gas is going out quicker than it comes in, and the exhaust consists mainly of burnt products mixed with a little air. Then at B the pressure begins to rise, and the air accumulates in the cylinder. At C the pressure falls rapidly, and the accumulated cylinder contents, which have had plenty of time to mix, are rapidly discharged, thus reproducing at this stage the conditions described in the last paragraph. Moreover, at C the cylinder pressure is higher than the air pressure, so that some of the cylinder contents (which still contain a large proportion of burnt products) will back into the receiver; some of the contents of the exhaust pipe must also at this point come back into the cylinder. A quantitative estimate of the effect of the variations on the loss of air could be made by the use of the principles enunciated earlier in this paper, but would be a long and complicated piece of work. It will be sufficient to observe that the general result must be to increase the loss. The holding up of the air and the backward and forward flow in the middle of the admission period will mix up the air and products of combustion, and will destroy the stratification which would otherwise exist. The author believes this cause to be sufficient to account for the difference between the results obtained with the water model and with the engine.

Though the theory of the charging process which has been suggested in this paper cannot be regarded as completely proved as regards details, the author has ventured to bring it to the notice of those interested in two-cycle engines in the hope of eliciting from them more facts about the loss to exhaust. It is to be regarded as a working hypothesis which may prove useful in the interpretation of data, but which will probably require modification in its details as more facts are accumulated. This remark applies more particularly to the corrections for stratification and for varying exhaust pressure. The simple theory based on the assumption of complete mixing and uniform cylinder pressure is, in the author's opinion, a very fair first approximation, which will give results of sufficient accuracy in most practical cases, and as such he hopes that it may prove of use to designers.—"Engineering."

CORROSION AND PROTECTION OF METALS.

A RATIONAL TEST FOR METALLIC PROTECTIVE COATINGS.*

A METHOD DEVISED FOR MAKING COMPARISONS ON THE DURABILITY OF GALVANIZING, SHERARDIZING AND LOHMANIZING.

By J. A. Capp.†

There are several processes commercially used for covering the surfaces of metals easily corroded or rusted, such as iron in its several forms, with other metals less easily corroded, or with metallic oxides. These may well be called "metallic" protective coatings in distinction from the types of coating which are in the nature of paints or their equivalent.

The object of the application of these metallic protective coatings is to

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†General Electric Company, Schenectady, N. Y.

enable the coated articles to resist atmospheric exposure without rusting for a longer time than they could withstand such exposure without protection. Obviously, then, the only final test of the efficiency of a given type of coating is actual exposure to the same sort of influences that the material is supposed to resist in service. If the coating is at all efficient this takes so long a time that more rapid methods of determining relative efficiencies become a necessity. The most commonly used methods of testing such metallic protective coatings are those of chemical attack, which in effect measure either the thickness or the weight per square unit of the protective coating. Such methods of chemical attack permit the comparison of results obtained from tests upon the same sort of coating, but difficulty is encountered when attempt is made to compare the results obtained by such tests on one sort of coating with those obtained on another character of coating. For instance, the well-known Preece test yields excellent comparative results on galvanized coatings. When, however, it is used for coatings applied by the sherardizing process, the results are not at all comparable. Neither is the Preece test applicable to coatings of tin or of lead. In the case of sherardized articles, it has been suggested that the coat, which is a combined structure of zinc and zinc oxide, together with some zinc-iron alloy, be removed in strong alkalies which will not attack the iron beneath. This would enable one to determine the weight of coating per unit of surface calculated to metallic zinc, but experience has shown that the results do not necessarily indicate the efficiency of the coat, and that it is not easy to determine the relative proportions of zinc and zinc oxide. Furthermore, comparison of the the efficiency of the coat, and that it is not easy to determine the relative sible when the sherardized coating is tested by solution in a caustic alkali, while the galvanized coating is subjected to the Preece test.

Some years ago, when testing electrical insulation such as is used for overhead line construction, we found that material which stood fairly well when immersed in water failed badly when exposed to the weather, especially if exposed during a hard rain. This led us to produce a rain in the laboratory by sending a stream of water through an ordinary rosette such as is used with a gardener's watering can. The results were encouraging, but too severe, because the individual streams played steadily on one spot and produced erosion. Then we tried an atomizing nozzle, projecting a cloud of moisture into a chamber in which the test specimens were exposed; the results were better, but there was still a possibility of some wear if the article was directly in the path of the stream and near to the nozzle. The problem seemed to be solved when care was taken in placing the articles to keep them out of the direct path of the jet issuing from the atomizing nozzle. As experience was gained with this type of test, as applied to insulating material, it was found that what seemed to be the essential requirement was the maintaining of an atmosphere substantially saturated with moisture; and this saturated-atmosphere exposure has been one of the tests regularly applied to all insulating materials intended for outdoor use since it was first worked out some fifteen years ago. It has been found to give reliable indications of the ability of insulation to resist weather, except, of course, as such ability is affected by extremes of heat and cold, erosion from the wind carrying dust particles, etc.

The problem of determining the resistance of protective coatings to weather corrosion is very similar to that of testing insulation for their weathering qualities. The conditions of exposure are the same, and hence there seemed to be no essential reason why the saturated-atmosphere test would not apply equally well to protective coatings as to insulation. Tests were begun several years ago to try out the method, and the only fault found with it was that it was somewhat slow. Good coatings did not show any signs of breaking down after several weeks of continuous exposure to the fog; yet there was encouragement in the fact

that bare metal began rusting in a few hours, and rust spots began developing on poorly protected surfaces in from a few days to a week.

The fact that more trouble is experienced with trolley-line suspensions along the seashore than with the same devices inland, led immediately to the trial of an atmosphere saturated with salt water, with astonishingly satisfactory results.

As now used, the test consists in exposing the articles in any convenient chamber into which there is projected an atomized spray of water saturated with common salt in solution, care being taken to avoid placing the test specimens directly in the path of the jet. To insure constant saturation, an excess of salt is kept in the water at the bottom of the chamber. The spray is produced by a jet of compressed air lifting the water to the nozzle, whence it is projected as a cloud. This apparatus is the common atomizer, so-called, used in the household. The chamber is necessarily not tightly sealed, but is open sufficiently to permit "breathing"; when used with an air jet, there is a slight pressure which is relieved through the breathing openings. If desired, the test may be modified by the use of a fine steam jet to raise the temperature of the atmosphere in the chamber. There is also the possibility of rendering the test atmosphere slightly acid or alkaline by suitable additions to the water in substitution for the salt. For use with plain water the closet generally used for cement testing does very well, provided care is taken that it is so arranged as to maintain the air practically at 100 per cent. relative humidity. When using salt solutions recourse must be had to the atomizing jet to insure the development of the salt fog.

When exposed as described articles have a very thin film of moisture over their surface, but there should be very few, if any, drops of sensible size on the objects. Obviously, the test is very searching, as all parts of the surface are exposed, and any pin holes or uncovered areas become evident. This gives one an opportunity to learn something of the efficiency of any protecting process in taking care of edges, sharp corners, porous spots in the metal surface, etc. By noting the character of the final general break-down, a very good idea of the evenness of the coating applied may be obtained.

The method of test may be applied to bare metals as well as to those coated to prevent rusting. For this purpose, the plain saturated atmosphere is apt to be better than a salt atmosphere, because the latter may be too severe and hence make comparisons rather difficult.

The salt-spray test, as we have called it, has been used in the laboratory with which the author is connected for a number of years, and during the last four or five years it has also been used commercially as a check upon the process of sherardizing which is in use. The coated articles are exposed to the salt fog, and are examined from time to time to note their surface condition. When the coated material is iron in any of its several forms, red rust begins developing as soon as the coat breaks down. This rust may appear in small pin points which gradually extend, or it may appear generally over the surface of the article. When the coating is relatively thin and poor, rust may develop in from 2 or 3 hours to 24 hours, or longer. A better coat will last 2 or 3 days, but a well-applied coat of requisite thickness will last at least a week. If no rusting is develepod in two weeks' time, it may safely be assumed that the life of the coating will be practically indefinite. These figures are based on experience with both sherardized and galvanized types of coating. Other types give results which lie in approximately the same range.

This method of testing is not offered in replacement of other methods of testing which have long been in use, especially when such tests are used solely for comparison on material treated always by the same process. It has, however, almost entirely displaced all such methods of test in our own practice, especially when comparisons are desired between processes of different character, because it is the only test which we have been able

to devise which approximates practical conditions, and yet yields results within a reasonably short time. The salt-spray test is only an exaggeration of what may be expected at the seashore and differs only in degree, not in kind, from the normal conditions under which the article is intended to be used.—"The Metal Industry."

TESTS FOR GALVANIZERS.

The copper sulphate and the lead acetate tests for galvanized material require care and accuracy in carrying out the details if comparative results are to be expected.

For the thorough testing of galvanized products it would seem advisable to employ the copper sulphate test for the purpose of indicating the uniformity of the coating or the thickness of zinc at its thinnest point, the lead-acetate test being used to find the amount of zinc deposited per unit area of surface, while the caustic-soda test gives evidence of the continuity of the coating, and furnishes also an indication of how the galvanized product stands the bending test. It is only by employing all of these tests for galvanized products that an intelligent idea of the comparative values of zinc coatings may be obtained and defects made evident.—"The Metal Industry."

CORROSION AND EROSION.

By Edwin Lewis.

The corrosion and erosion of metals is one of the greatest difficulties the engineer has to contend with. Frequently corrosion and erosion act together, as for example, the corrosion of brass and copper tubes in locomotive fireboxes. The sulphur and other gases act on the copper and corrode it, and the fine ashes erode the metal by cutting it away. As is well known, corrosion is not limited to the non-ferrous metals; in fact, the most easily corroded common metal is iron, but engineers protect it as much as possible by coating with tin, zinc or paint. It can also be rendered "passive" and is then non-corrodible, but the various processes are patent. The corrosion of non-ferrous metals is not easy of prevention.

Corrosion may be divided into classes, for example, corrosion due to oxidation; chemical corrosion due to solvent action of acid or alkaline liquid; corrosion set up in the metal itself; corrosion set up by different metals in contact with one another in a saline or acid liquid; corrosion due to the actual decay of the metal, and erosion. Is it any wonder then that it is impossible for any one to draw up a specification of a metal and say this metal will withstand corrosion? It is unfortunate for engineers that gold and platinum are so expensive, they are practically the only metals which will withstand corrosion. Of the various kinds of corrosion we have mentioned some of them have a tendency to act together and exaggerate the fault. The principal non-ferrous metals affected by oxidation corrosion are zinc and copper sheets where exposed to the weather; in the case of copper the oxidation is assisted by carbonic-acid gas forming a carbonate of copper. This latter corrosion is very beautiful from an artistic point of view; some old roofs look very well in this natural coating. It cannot be obtained in the laboratory anywhere near equal to the natural corrosion. In the case of zinc the formation of oxide has to be prevented by paint or the metal would rapidly corrode away.

All commercial non-ferrous metals are attacked by acid liquids to a certain extent even when dilute; also sea water and alkaline liquids attack them. Chemically pure metals are, as a rule, much more easily attacked than those not so pure; this is especially the case with electrolytically-deposited metals. Metals in the electrolytic-deposited state seem to be in a different amorphous form from the same metal melted down. There are two types of non-ferrous metals. There is the metal with only 1 microscopic constituent in it and the type with 2 or more constituents. The anti-corrosive properties of these two types are different. Take for instance 70/30 brass; this consists of 1 constituent only, and take 62/38 yellow metal which has 2 constituents. The replacement of 1 per cent. zinc by 1 per cent. tin in the first makes a metal which will resist corrosion better than 70/30 brass. In yellow metal, if you make it of chemically pure copper and zinc and make it into sheet and put it into a corrosive liquid, the beta constituent begins to lose zinc until only practically copper is left, then this begins to react with the alpha constituent in electrolytic contact, and the zinc is dissolved out until the whole becomes practically copper. There are various ways of preventing this. The addition of .25 per cent. tin, .25 per cent. manganese, or 1 per cent. lead, obtained by the addition of a commoner spelter, will give an alloy which will prevent the dissolution of the beta constituent, and so long as the beta constituent is unattached the metal will not corrode.

Further down the scale we have the Delta, Sterro and manganese bronzes. These contain approximately 55 per cent. copper and 1 per cent. to 3 per cent. of tin, iron or manganese, either together or separate. Their anti-corrosive properties are similar. In these alloys the beta constituent is present in larger quantities than in the yellow metal series, and it will hold in solution more tin, iron or manganese; the result is that these alloys are far superior to yellow metal alloys for withstanding, say, the corrosive action of acid mine waters.

The strength or hardness of metals has no relation to their resistance to corrosion by solution in acids or similar liquids. A soft metal will frequently withstand corrosive influences far better than a hard one; an example of this is lead, which will withstand the corrosive action of sulphuric acid even when fairly strong. This metal, however, is quite useless to withstand erosive action as distinct from corrosion. It is said that 2 per cent. lead in condenser tubes will last better than pure 70/30 brass and 1 per cent. lead in yellow-metal sheathing will enable it to withstand corrosion is sea water better than yellow metal with only 0.3 per cent. to 0.5 per cent. lead. There are two probable explanations of this; it is possible that in the process of drawing or rolling a thin film of lead forms round the constituent crystals and prevents or checks the action of sea water; another explanation is that the lead is in small patches evenly distributed through the mass, and this acts in electrolytic conjunction with the other constituents, and thus hinders their corrosion until it has itself been dissolved away. Which of these explanations is the correct one, we cannot say.

An example of lead in an alloy which is deleterious owing to erosive action, as distinct from corrosive action, is in gun-metal fittings for steam boilers. We know of cases where the fittings had begun to leak seriously in a comparatively short time. Acid in the feed water was suggested, but an analysis disclosed the presence of a large percentage of lead in the metal. If it is at all possible lead should never be present in gun-metal fittings for high-pressure steam boilers.

Corrosion set up by two dissimilar metals in contact with one another in a saline or acid solution is of fairly frequent occurrence, but it can always be avoided. Yellow metal should never be in contact with iron or gun metal, as it sets up electrolytic action in acid, saline and even slightly alkaline solutions. Copper and iron should never be together under these conditions.

Certain alloys decay naturally without any apparent cause. Frequently this is due to the breaking up of the crystalline structure. Erosion and corrosion are the cause of loco tube failures, under the conditions under which they are used. A hard metal is essential to resist the erosive action of the fine ashes which are forced through the tubes almost like a sand blast. A metal is required which has a relatively high tensile strength at 250 degrees F. It is found by experience that arsenical copper is the best metal for this purpose. Copper containing about .07 per cent. phosphorus cast from crucibles from a mixture of electrolytic and B. S. copper gives a good tube, but it is not so favorably looked upon by engineers nowadays as the arsenical copper. Nickel alloys containing 2 per cent. nickel are sometimes recommended. We believe that nickel-copper alloys are used successfully for stay bolts in locomotives. The causes of corrosion and erosion are fairly well known, and, if the whole circumstances are known, competent chemists can find out the cause of any ordinary case of corrosion.—"The Metal Industry."

METALS.

STUDY OF THE STRENGTH OF NON-FERROUS CASTINGS: COMPARISON OF DIFFERENT TEST SPECIMENS.*

AN ARTICLE GIVING SOME LIGHT ON THE QUESTION OF WHY TEST SPECIMENS DIFFER FROM THE CASTINGS THEY REPRESENT.

By L. P. Webbert.

The object of the investigation described in this paper is to note the changes in strength that occur in different thicknesses of metal castings made from the non-ferrous metals met with in engineering practice. The knowledge desired, from the machine-designer's point of view, is to know how to proportion the separate parts of a design with regard to strength, and to know what physical properties to expect from a casting at different points or as a whole.

DESCRIPTION OF TEST SPECIMENS.

Some metallurgists strive to adopt a test specimen to represent the strength of an alloy which will give the maximum results obtainable for that metal. Such test specimens give results that are interesting but tend to mislead. Quite a number of different types have been suggested for adoption as a standard test specimen, but when we consider the specifications that must be followed in practice our choice becomes decidedly restricted to a few forms. The specifications state that a test specimen is to be a part of the casting and is not to be cast separately. The test specimen must receive the same heat treatment—that is, no chilling of the test specimen is allowable—and must be turned down to a stated diameter.

There are two styles of test specimens made use of in practice, one for the copper-tin alloys and the other for the copper-zinc alloys. The first is that used on 88–10–2 castings (copper 88 per cent., tin 10 per cent., zinc 2 per cent.). This test specimen, as cast with the casting, has the dimensions shown in Fig. 1 (*a*). A ⅛-inch gate running the entire length of the test specimen connects it with the casting. A casting with the test specimen attached is shown in Fig. 2. Being gated in this manner allows the test specimen to be filled quickly with metal and has the advantage of giving the same rate of cooling to every part of the specimen. When the

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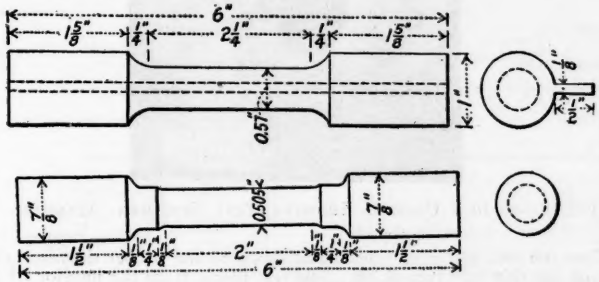
test specimen is detached it is turned down in a lathe to the proper diameter and form as shown in Fig. 1 (*b*). In Fig. 4 (*c*) are shown the forms placed in the parting of the mold; two forms to give test specimens 0.505 inch in diameter, and one to give a test specimen 0.798 inch in diameter. When a test specimen is to be placed at another part of the casting, cores are made use of as shown in Fig. 5 (*b*) and (*c*). At (*b*) are shown cores to give 0.798-inch test specimens and at (*c*) are shown those to give 0.505-inch test specimens.



(*a*) As Cast.
(*b*) Finished.

FIG. 1.—TEST SPECIMEN FOR 88–10–2 CASTINGS.

The test specimen as shown in Fig. 1, with a finished diameter of 0.505 inch, is used more than the test specimen having a finished diameter of 0.798 inch. A drawing of the 0.798-inch specimen would be similar to Fig. 1, but would show larger diameters and greater thickness of gate.

For the copper-zinc alloys (manganese-bronze and brass) a bar of metal 1 by 1¼ by 6 inches is cast on the side of the casting. Fig. 4 (*b*) shows two patterns for this style of test specimen, the diameter of which is to be 0.505 inch. These patterns are placed against flat surfaces. For curved surfaces different patterns are made to fit the curvature of the castings. The round part of the pattern shown in Fig. 4 (*b*) allows the pattern to be drawn easily from the sand. Comments on this style of test specimen will be made again in this paper.

It is well known that to obtain the highest results from 88–10–2 test specimens the least amount of metal should be turned off the specimen. In comparing Fig. 1 (*a*) with (*b*) it will be noted that 0.065 inch of metal is turned from the test specimen. In the "skin" of the casting lies the greatest strength as the foundryman puts it. To illustrate: A large valve body, ¾ inch in thickness, made from 88–10–2 metal, was cut up to procure test specimens from the flange and body of the casting, in order to compare the strength of these with the strength of the test specimen attached to the casting. The test specimen (0.505 inch in diameter) gave an ultimate tensile strength of 40,000 pounds per square inch and an elongation in 2 inches of 40 per cent. From the body the following results were obtained:

	Tensile strength, lb. per sq. in.	Elongation in 2 in. per cent.
1	25,800	13.0
2	25,200	11.0

From the flange the following results were obtained:

	Tensile strength, lb. per sq. in.	Elongation in 2 in. per cent.
1	23,650	11.0
2	18,850	5.0

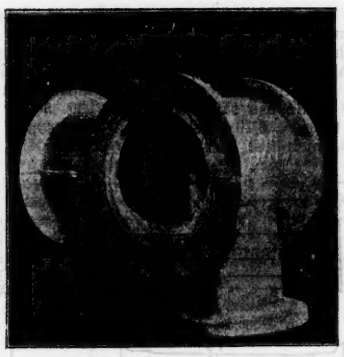


FIG. 2.—88–10–2 CASTING SHOWING TEST SPECIMEN ATTACHED.

When the test specimen was turned down to the proper diameter very little of the skin was turned off. The test pieces from the interior of the metal possessed no skin and gave lower results. The results emphasize the fact that the test specimen attached to the casting exaggerates the strength of the casting as a whole.

If the diameter of this style of test specimen is increased lower results are obtained. Let us compare the 0.505-inch diameter test specimen (0.2 square inch in area) with the 0.798-inch diameter specimen (0.5 square inch in area). The ratio of the area of the 0.506-inch test specimen to the circumference is smaller (area ÷ circumference = 1.26) than the ratio of the area of the 0.798-inch test specimen to its circumference (area ÷ circumference = 1.99). In the former case we state that there is more skin, so to speak, to the specimen and consequently more strength obtainable than with the larger diameter specimen. The author has averaged 61 tests from large castings having the 0.505-inch test specimen and gives the following average: Tensile strength, 46,580 pounds per square inch; elongation in 2 inches, 38.7 per cent. Among these tests a maximum tensile strength of 51,650 pounds per square inch is noted, with an elongation of 62.5 per cent., which is also the maximum elongation. The minimum tensile strength among the tests is 39,100 pounds per square inch, with an elongation of 25 per cent. The minimum elongation is 20 per cent. The specifications under which these castings were made required a minimum tensile strength of 30,000 pounds per square inch, and a minimum elongation of 20 per cent. in 2 inches. A specification from another source called for a minimum tensile strength of 35,000 pounds per square inch and a minimum elongation of 20 per cent. in 2 inches for a test specimen of 0.5 square inch area (0.798 inch in diameter). This style of test specimen was placed on ten large 88–10–2 worm wheels. The tests gave an average tensile strength of 36,324 pounds per square inch, and an average elongation of 27.1 per cent. The maximum tensile strength among the tests was 42,800 pounds per square inch, with an elongation of 36 per cent., which was also the maximum elongation. The minimum tensile strength was 29,300 pounds per square inch, with an elongation of 17 per cent., which was the minimum elongation. Among these ten wheels there were two—one with a test specimen that pulled 32,500 pounds per square inch, with an elongation of 21 per cent., and another with a tensile strength of 29,300 pounds per square inch, and an elongation of 17 per cent.—that did not pass specifications. No doubt exists that had the 0.505-

inch diameter test specimen been used all tests would have given higher results.

We can conclude, therefore, that for this style of specimen used on copper-tin alloys the smaller ratio of area to circumference of test specimen gives the greater strength. This is due to the fact that in general the rate of freezing of the metal is an important factor in influencing the strength of the casting. The skin of the casting receives the chill of the mold, is the first to freeze, and shows the smallest structure or grain.

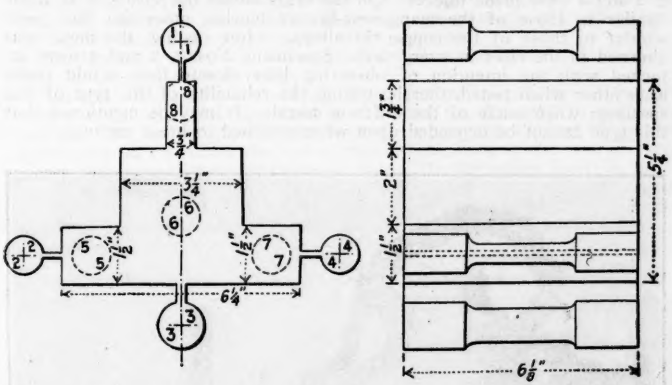


FIG. 3.—TEST BLOCK SHOWING DIMENSIONS AND NUMBERING OF TEST SPECIMENS.

From the skin, freezing of the metal takes place gradually toward the center of the casting. The rate of freezing depends upon the following factors: (1) The thickness of the casting; (2) the temperature of the metal entering the mold; and (3) the conductivity of the mold.

VARIATIONS OF THE STRENGTH OF METAL AT DIFFERENT PARTS OF A CASTING.

In order to study the effect of the rate of freezing upon the strength of the metal, castings of copper-tin and copper-zinc alloys were made as shown in Figs. 3, 4 (*a*) and 5 (*a*). Fig. 5 (*a*) shows a block made of 88–10–2 metal with the test specimens attached which are used for this metal. Fig. 3 is inserted to show the arrangement of specimens and numbering on blocks made of copper-tin and copper-zinc alloys. Test specimens Nos. 1, 2 and 4 are of the pattern shown in Fig. 1. No. 3 is a similar test specimen to be turned down to a diameter of 0.798 inch. Nos. 5, 7 and 8 are test specimens used on castings made of copper-zinc alloys (manganese-bronze and brass). A bar of metal is cut out of the center of the casting and turned down into a test specimen to represent the strength of the metal at the center. The relative advantages of these types of test specimens can be studied, since they are cast together on the same casting, are made from the same metal, and receive the same heat treatment. The specimens on all blocks made were numbered as shown in Fig. 3. Tables I and II give the results of all tests. The test specimens were not threaded but were pulled with grip jaws in the testing

machine. In turning down the test specimens, Nos. 5, 6 and 7, were given a diameter of 0.798 inch. The diameter was later changed to 0.505 inch in order to obtain uniformity in the size of the test specimens. Test specimen No. 3 was given a diameter of 0.798 inch for all blocks. In some instances this specimen was turned down to a smaller diameter when found slightly defective.

A few changes had to be made when casting the manganese-bronze blocks, on account of the nature of the metal. The risers were made larger, the sprues longer and the gates connecting test specimens Nos. 1, 2, 3 and 4 were made thicker. On the brass blocks the sprues were made similar to those of the manganese-bronze blocks; otherwise they were similar to those of the copper-tin alloys. After casting, the metal was churned in the riser in every case. Specimens Nos. 1, 2 and 4 were attached with the intention of observing how closely they would check each other when tested, thereby testing the reliability of this type of test specimen when made of the different metals. It may be mentioned that this type cannot be depended upon when attached to brass castings.

(*a*) (*b*) (*c*)

FIG. 4.—(*a*) MANGANESE-BRONZE TEST BLOCK.
(*b*) MANGANESE-BRONZE TEST SPECIMENS.
(*c*) TEST SPECIMENS FOR COPPER-TIN ALLOYS.

With some alloys a green-sand mold was made. This mold was filled immediately after the dry-sand mold was filled. The metal for both molds was poured from the same crucible. The castings made in green sand gave results that showed no decided variation from those made in the dry sand. The green-sand molds were soon discontinued. Only the average results from the green-sand blocks are given in Table II.

The block for alloy No. 1 was cast after the casting shown in Fig. 2 was poured. This metal was made from the best copper, tin and zinc obtainable, but was not remelted. The temperature was not taken when the block was cast, but was lower than the pouring temperature usually desired for such a small casting. The specimen attached to the casting in Fig. 2 was pulled and gave a tensile strength of 49,150 pounds per square inch and an elongation of 47.5 per cent.

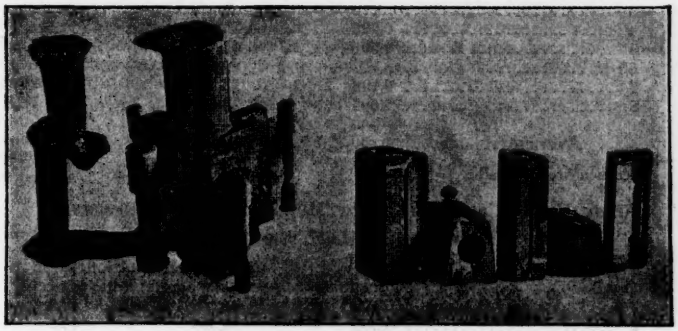
For alloy No. 2 a different procedure was adopted. In order to get a perfect and homogeneous alloy the metals for this block were alloyed and

the resulting alloy pigged. The metal was remelted, brought to the proper temperature in the furnace and cast. The casting after being cut up was found to be perfect.

Alloy No. 8, manganese-bronze, gave trouble. At the center of the block near the top sponginess occurred, due to shrinkage. In practice this trouble is overcome by pouring metal at a higher temperature from another crucible into the riser during churning to liven up the metal in the center. Only one attempt was made to make a block of manganese-bronze pulling about 80,000 pounds per square inch. This casting was a failure due to the little shrink holes occurring throughout the casting. One test was good, No. 1, which gave a tensile strength of 79,500 pounds per square inch and an elongation of 24 per cent.

The block for alloy No. 9 was not finished and is inserted in Table II because the analysis was made.

Methods of Manufacture.—The alloys used were made by melting the copper under charcoal, then adding the zinc, tin and lead in the order named. The temperature of the melted copper was allowed to become sufficiently high to cause the zinc to flare when added in the case of those alloys requiring a large amount of zinc. To the alloys high in tin, 1 ounce of 15-per-cent. phosphor-copper was added for every 100 pounds of metal after the other metals had been alloyed, the object being to introduce sufficient phosphorus to remove the oxides and leave a trace of phosphorus in the alloy.



(*a*) (*b*) (*c*)

FIG. 5.—(*a*) 88–10–2 TEST BLOCK.
(*b*) AND (*c*) CORES USED FOR SPECIMENS NOS. 1, 2, 3 AND 4, FIG. 3.

Manganese-bronze was made by introducing an alloy of iron, manganese and tin into the melted copper when sufficiently hot. This alloy, which is made by melting together iron and ferro-manganese, has an approximate composition of 54 per cent. iron, 21 per cent. manganese and 25 per cent. tin. When this mixture is melted the tin is introduced to lower the melting point. The amount of this alloy introduced depends upon the percentage of iron desired in the bronze. Tin is added later with the zinc to keep the percentage of tin at 0.8. After the above alloy had dissolved in the copper the aluminum was added and then the zinc and tin. The manganese bronze was pigged before being used again.

TABLE I.—ANALYSES OF ALLOYS.

Alloy No.	Percentage of Copper.	Tin.	Zinc.	Lead.	Iron.	Manganese.	Aluminum.	Phosphorus.
1	88.31	8.49	3.20	....	....	....	....	trace
2	87.98	10.64	1.28	0.10	....	....	....	trace
3	86.78	6.31	5.96	0.92	0.03	....	....	trace
4	84.28	11.31	4.15	0.06	0.06	....	....	trace
5	62.81	0.79	26.18	0.09	0.05	0.02	0.06	.....
6*	62.81	0.79	26.18	0.09	0.05	0.02	0.06	.....
7	84.49	....	15.49	....	0.02	....	....	.....
8†	....	....	....	....	....	....	....	.....
9	57.66	0.84	39.85	....	0.69	0.16	0.58	.....
10	89.08	7.48	3.00	0.07	....	....	....	0.20

*Alloy No. 5 remelted.
†Analysis not made. Manganese bronze.

TABLE II.—RESULTS OF TESTS.

ALLOY NO. 1.—COPPER–TIN; NEW METAL; NOT REMELTED.

Test Specimen No.	Diameter of Test Specimen, in.	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent.
1	0.505	40,800	28.0
2	0.505	43,250	32.0
3	.....	.....	....
4	0.798	35,720	24.5
5	0.505	33,750	22.5
6*	.....	.....	....
7	0.798	33,080	21.0
8	0.505	34,600	24.0
Average	.....	36,866	25.3

*Specimen broke in lathe.

ALLOY NO. 2.—COPPER–TIN; NEW METAL; PIGGED AND REMELTED.

Temperature of Metal, 2,300 *degs. F.*

Test Specimen No.	Diameter of Test Specimen, in.	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent.
1	0.505	51,250	42.5
2	0.505	50,300	40.5
3	0.798	40,660	23.5
4	0.505	50,400	39.0
5	0.798	33,740	14.0
6	0.798	28,560	9.5
7	0.798	34,200	16.0
8	0.505	40,550	28.0
Average	.....	41,201	26.6

In taking pyrometer readings no attempt was made to get the casting temperature at the mold, because the pyrometer in use was a base-metal couple that was not sufficiently sensitive to give quick accurate readings; also because pyrometer readings are best made at the furnace, on account of the necessity of removing the metal from the furnace when the proper temperature has been reached. This procedure does not allow the metal to overheat or "soak" (that is to remain in the furnace an unnecessary length of time), which injures the alloy. In Table II the temperature given is the temperature taken at the furnace.

CONCLUSION.

On comparing the different tests we can conclude that the 88–10–2 test specimen as shown in Fig. 1 is convenient to use on copper-tin alloys. Incidentally, it may be noted that the average strength as given in Table II is approached by the strength of specimens Nos. 3 and 8 for the copper-tin alloys, and by No. 8 for the copper-zinc alloys. The 88–10–2 specimen with its narrow gate was attached to a block of manganese-bronze with no success. The gate was then widened to the thickness of the test specimen at the middle as used on the blocks for alloys Nos. 8 and 9. The adopted test specimen for manganese-bronze (0.505 inch diameter) took the form shown in Fig. 4 (*b*). The 88–10–2 specimen was not successful with brass due to small cracks forming in the specimen. The small cracks were not noticeable until the specimen was tested. The rate of freezing appears not to affect the copper-zinc alloys to as great an extent as the copper-tin alloys. The strength of alloy No. 2 varied from a tensile strength of 51,250 to 28,560 pounds per square inch, while that of alloy No. 7 varied from a strength of 31,700 to 29,000 pounds per square inch. With this copper-zinc alloy no cracks developed in the test specimens Nos. 1, 2, 3 and 4.

Considering a test specimen to represent the strength of a copper-zinc alloy, we can choose such a specimen as Nos. 5 or 6 for a diameter of 0.798 inch, or No. 8 for a diameter of 0.505 inch (the specimen shown in Fig. 4 (*b*) is identical with No. 8). But when the copper-tin alloys are considered we cannot make a choice. In a gear blank made from 88–10–2 metal, the surface of the metal is cut away to form the teeth of the gear. It is evident that the strength of the teeth could not be represented by test specimens Nos. 1, 2, 3 and 4. If a bar of the same metal is turned down to the size of a bolt, the designer's calculations must be based on the strength of the metal represented by specimens Nos. 5 and 7.

In this paper the author has endeavored to point out, with a limited number of tests, how the strength of metal varies with changes in the thickness of castings, what strength to expect from different alloys, and how a study was made of the different types of test specimens used in practice.—"The Metal Industry."

SOME CONSIDERATIONS AFFECTING SPECIFICATIONS FOR WROUGHT NON-FERROUS MATERIALS.*

SOME REASONS WHY IT IS DIFFICULT TO FORMULATE RIGID AND INELASTIC LIMITS TO SPECIFICATIONS.

By William Reuben Webster.†

INTRODUCTORY.

It is the purpose of this paper to enumerate and discuss some of the factors which affect the construction of specifications for wrought non-ferrous materials. While the use of these products in construction is large and important, the variety of uses is so extensive that with some exceptions not many data are available to the engineer desirous of defining his necessities.

Attention will be particularly confined to the copper-zinc alloys as representing the most comprehensive group of materials that are fabricated

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by wrought processes into sheets and strips, rods and bars, brazed and seamless tubes, and wire.

PROPERTIES OF COPPER–ZINC ALLOYS.

Copper and zinc alloy to form malleable and ductile materials in all proportions from about 55 per cent. up to pure copper, and over this range the products exhibit a normal variation of physical properties which is very great. Moreover, the properties normal to any particular proportion of the two constituents can be greatly modified by the processes of cold working and heat treatment. Other modifications are produced by the presence, either accidental or intentional, of other elements, more particularly lead, iron and tin. The effects of these vary in turn with the percentage of copper present and may be harmful or beneficial according to the purpose for which the material is required. Lead causes it to work freely under a tool but decreases ductility, the latter effect in turn becoming more pronounced with decreasing percentages of zinc. Tin, on the other hand, decreases ductility greatly in the presence of considerable percentages of zinc. It is this very wide range of properties which can be imparted to the copper alloys in the wrought form, together with their non-corrodibility, which gives them the great value which they possess.

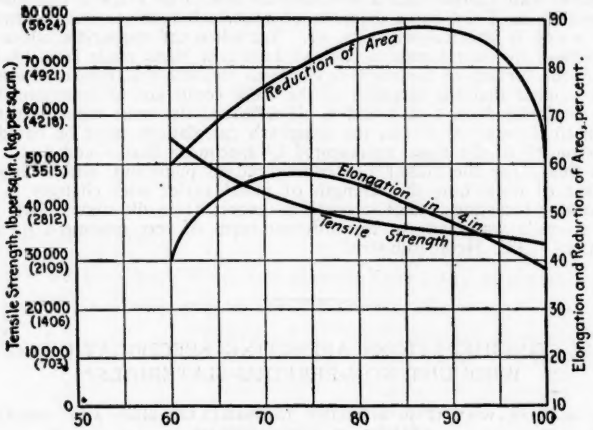

FIG. 1.—CURVES SHOWING VARIATION IN PHYSICAL PROPERTIES OF COLD-ROLLED AND ANNEALED COPPER–ZINC ALLOYS, DUE TO VARYING PERCENTAGES OF COPPER AND ZINC.

At the same time, formulas have not been deduced which will accurately correlate components and properties to uses, although experience has determined with more or less correctness those things which should be avoided when any known purpose is to be met. Fig. 1 shows the variation in physical properties with the proportion of copper and zinc when cold rolled and annealed.

It is general practice to produce the alloys by melting the constituents in crucibles containing about 200 pounds, so that this quantity represents the unit heat. To determine all the important constituents of the product of each crucible charge is manifestly commercially impracticable, so the range of tolerable variations as determined by individual analysis must of necessity be comparatively large.

VARIATIONS IN COMPOSITION.

Departures from a desired composition as influenced by variation in the copper are not difficult to control, because ingot copper is produced in large furnace charges, permitting of accurate sampling and determination. Such, however, is not the case with zinc, each plate of which (about 40 pounds) not only shows an individual lead content of its own, but on account of the fact that lead and zinc do not alloy, will show widely different proportions in various parts of the same place. Moreover, zinc is highly volatile, so a certain proportion of it is lost during the alloying process. This amount is difficult to control within close limits. It is governed by the proportion of zinc in the charge, the temperature of the crucible contents at the time the zinc is introduced, and the time elapsing between the introduction of the latter and the pouring of the crucible contents. It is evident also that some variation is due to the limit of error in weighing the charge, and that the large number of individual weighings necessary in producing any considerable quantity of brass affords an opportunity for occasional error. More or less variation also occurs in different parts of the same bar. As a result of all these opportunities for variation, the departure which any individual bar or ingot may show from the desired composition is considerable, its limit being the sum of all the variations due to each of the causes enumerated.

In addition the errors of chemical analysis need consideration. The Bureau of Standards recently prepared an accurate sample of sheet brass and made a careful determination of its constituents. Portions of this sample were sent to eleven different chemists accustomed to this class of work for check analyses. The extreme variations reported to the bureau showed for copper 0.15 per cent. of the total copper as determined by the bureau, for zinc 0.89 per cent., for lead 5.2 per cent., for iron 13.8 per cent. and for tin 10.2 per cent. It should be borne in mind that these determinations were made under conditions conducive to much more than commercial accuracy.

Three qualities of copper are ordinarily employed, namely, lake, electrolytic and arsenical. The differences in the resulting product due to the employment of any one of these three grades is not definitely established. In the early days of the industry electrolytic copper was liable to contamination, but such a condition no longer exists. Several grades of spelter are in general use, the difference being due primarily to the lead content.

It is customary to make up the mixtures with certain proportions of scrap. The term scrap as here employed is not at all synonymous with junk. Good practice tolerates scrap only with a known history and of known composition. Properly safeguarded in this respect the use of scrap is advantageous. It is much more difficult to produce a thoroughly homogeneous mixture when the entire charge is composed of unalloyed copper and spelter.

INFLUENCE OF THE CASTING PROCESS.

The casting process, besides being the cause of variations in the composition of the finished product, affords other opportunities for variation in the quality. When properly performed, the bar, billet or ingot should be free from blowholes, gas cavities or dirt in the interior, and from cold-shot or other surface imperfections on the exterior. Improper or unskilled casting profoundly affects the strength and ductility of the ingot.

The surface of molten brass becomes instantly covered with a thick film of oxide on exposure to the air, and this oxide must be prevented from becoming incorporated in the solidified metal. Two instances will illustrate the importance of proper casting. Ingot copper of the finest character, as received from the refining furnace, is neither very ductile nor malleable when cold, but when properly melted and cast from a cru-

cible, it becomes highly so. A properly cast billet should show no pipe at the upper end, and when improperly cast a considerable pipe may occur. Fig. 2 shows a section of the upper part of a billet properly cast, and Fig. 3 of one improperly cast. The cut across the top of the billet in Fig. 2 shows the portion ordinarily discarded.

FIG. 2.—SECTION OF A PROPERLY CAST BRASS BILLET.

The crucible charge is cast into several different forms according to the use for which it is intended. If for sheet brass or strip, it is cast into bars usually about 1 inch thick and of a width varying from 4 to 14 inches, according to the width of the sheet required. The length is such that the standard crucible charge will make two bars. Wider sheets are produced by rolling the bars crosswise in the rolls until the required width is reached, or by cutting a partially rolled bar into lengths of approximately the required width and cross rolling to the finished thickness, according to the practice generally followed in rolling sheet steel.

FIG. 3.—SECTION OF AN IMPROPERLY-CAST BRASS BILLET.

Mixtures which admit of hot rolling are cast usually of greater cross-section, and of varying weight according to requirements. The extrusion process employs a billet 6 inches or more in diameter, weighing 150 pounds or more, according to the power of the machine employed.

OPERATIONS EMPLOYED IN MAKING SHEET AND STRIP.

Considering first the bar intended for sheet or strip, the various operations affecting the finished product will be discussed. After being cast, the bars have their gates or shrinkheads cut off. At the same time, the

cut and exterior surfaces are carefully scrutinized for evidences of improper casting, and should any be found, the unsatisfactory bars are cut up to be recast. From the shears, the bars are then placed in an annealing furnace, heated to redness, withdrawn from the furnace and allowed to cool. They are then given several passes through the breaking-down rolls, being reduced 40 to 50 per cent. in thickness. After breaking down, they are again annealed and overhauled. This last operation consists in scraping or cutting the surface of the bar with a reciprocating or rotary tool for the purpose of removing surface defects. This process affords opportunity for an efficient inspection, any defects in the casting being readily observable.

Rolling and annealing operations now alternate until the material is reduced to the desired thickness. The former operation increases the tensile strength, elastic limit and hardness, while reducing the elongation and reduction of area. Annealing removes the effect of rolling. This latter statement is subject to some modification in that the annealed cast bar has not quite the same physical qualities as after rolling and annealing. The effect of annealing is proportional to the temperature to which the metal is subjected. Characteristic curves showing the effect of cold rolling and of annealing are given in Figs. 4 and 5. Different mixtures give widely different curves.

Before the material is taken to the finishing rolls, it is pickled in a weak sulfuric-acid solution, which removes the oxidation and discoloration due to the annealing process, after which it is rinsed in water. The action of the pickle is not complete in that certain irregular surface discolorations or stains frequently remain.

The final rolling process determines the finished thickness or gage and also the temper, both of which are subject to considerable variations from that desired. Strips of metal after passing through a rolling process will show two variations in thickness; one is a variation from side to side or across the width of the strip, the other from strip to strip or sometimes from one end of the strip to the other. The former variation differs in extent for different widths, thicknesses and tempers, and cannot be entirely eliminated. It is, however, quite constant in any individual lot. The latter variation is due mainly to variations in hardness and thickness of the strip before passing through the rolls. This variation may be due to differences in composition or differences in degree of annealing. When a strip is passing through a set of rolls the stress tending to separate the rolls is so great that a considerable amount of elastic deflection takes place not only in the rolls, but also in the housings. This deflection is proportional to the stress, which is in turn proportional to the initial hardness and thickness of the metal.

It is the final rolling also which determines the temper of the material, this depending upon the amount of rolling given it after the final annealing. Fig. 4 indicates the wide range of properties due to variation in the amount of temper, and also shows the influences which the variation just discussed will have upon it.

A third quality due to the final rolling is flatness or freedom from buckles, more particularly in cases finishing with a temper. Subsequent flattening operations can more or less completely remove such buckles. All of the above variations can be modified by skillful rolling but cannot be entirely prevented.

Following rolling, the material if required with a temper is ready for the finishing operations. If required to be soft it is annealed, pickled, washed and dried out, the last operation being, as its name implies, for the purpose of quickly removing the rinsing water to prevent tarnishing. The strip is now ready to be cut to width and length. The former is done by passing the strip between rotary shears or slitters, which may merely re-

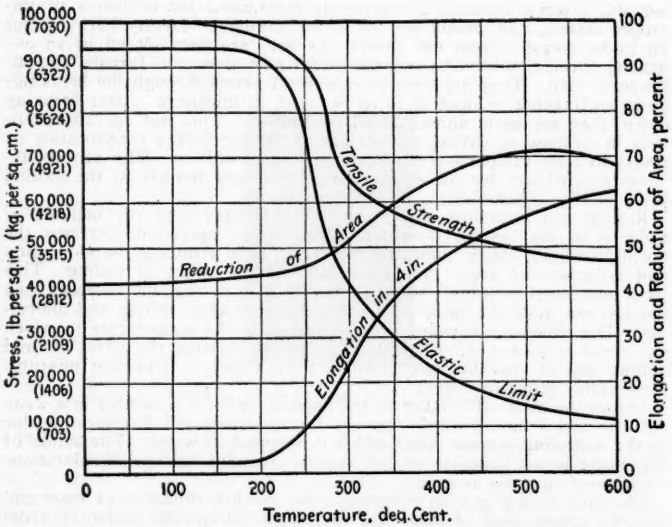

FIG. 4.—CURVES SHOWING VARIATION IN PHYSICAL PROPERTIES DUE TO ANNEALING HARD-ROLLED BRASS AT VARYING TEMPERATURES.*

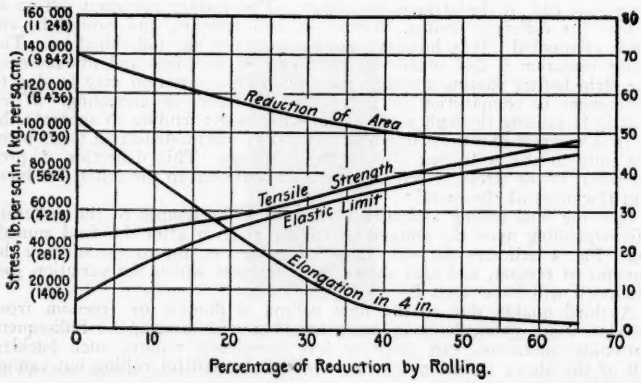

FIG. 5.—CURVES SHOWING VARIATION IN PHYSICAL PROPERTIES OF ROLLED SHEET BRASS, DUE TO VARYING AMOUNTS OF COLD ROLLING.

move the edges so as to produce a uniform width, or may cut it into a number of narrow strips. Because of the variations of thickness across the strip above referred to, the strips cut from the edges will always be

*At the time the tests were made from which these curves were plotted no accurate means of temperature measurement was available. The temperature scale is therefore presented as only approximate.

thinner than those nearer the center. Another variation becomes apparent at this point, namely, a variation in longitudinal straightness. One cause of this is due to failure to roll the strip straight caused by unequal reduction of its two sides. In addition, when a strip is finished with a temper, even though it is straight as rolled, it may, if slit into a number of strips, become longitudinally curved due to unequal tension between the center and side elements. In the slitting operation the strip is usually handled and shipped in a coil if not too thick, but may be required to be cut to some specific length and shipped flat. This usually produces a certain percentage of pieces of unequal length, which percentage increases inversely as the number of lengths which the original strip will make. If the net length of the strip is 20 feet and is required in 8-foot lengths, two of the latter and one 4-foot length will be produced.

TEMPER.

Alloys in sheet form will divide into two groups, those which are required soft or annealed and those having a temper. The former are usually for uses which involve distortion, producing flow of the material, and the qualities requiste for highest suitability vary somewhat with the method by which this flow is accomplished. Properties which permit the maximum amount of stretch will not necessarily equally admit of change of shape involving flow between supporting surfaces, as in drawing operations. Again, a condition permitting of maximum stretch due to complete annealing may result in a roughening of the surface due to large crystal structure, which will materially interfere with subsequent polishing operations. With tempered brass stiffness is the chief requisite, modified by ability to meet lesser amounts of distortion.

CLASSIFICATION OF KIND AND QUALITY.

Practice and trade usage have classified the copper-zinc alloys in sheet form into a number of groups according to the percentage of copper, the quality of spelter employed, and the added lead content. Several grades of temper are also recognized. The well-nigh universal test of quality, however, is the pragmatic test, the ability to meet the specific need of the user. These needs are arrived at by purely tentative methods and are satisfied by considering them in the light of experience. Attempts to quantitatively define needs, and to predict their satisfaction in terms of measurement have not as yet been either numerous or highly successful.

DETERMINATION OF REJECTION LIMITS.

It is manifest that in such attempts difficulty will be encountered in establishing rejection limits, because of the number of variables governing the various factors. The possibility of concurrent variations in a number of cases demands quite wide limits. Moreover, since each crucible charge constitutes a heat or lot, consideration must be given to the fact that no method of obtaining a single sample representative of anything other than the crucible charge from which it is drawn is possible.

As previously stated, rods may be made by the extrusion process, by hot or cold rolling, and by drawing. The first three are usually roughing processes, although all are extensively employed as final processes.

MANUFACTURE OF RODS AND BARS.

In the extrusion process, the cast billet is heated to redness and forced hot through a die. The resulting rod or bar may then require only to be cut to length, but is frequently subsequently drawn cold through a die in order to bring it more accurately to dimensions, give it a temper and improve its finish. When the required section is relatively heavy each billet

produces one continuous length; but with smaller sections two or more are made simultaneously. This process is applicable only to those mixtures which are readily extrudable and is particularly effective in producing rods of irregular or difficult profiles.

More or less departure from specified cross-sectional dimensions occurs, which may be partially corrected by subsequent cold drawing. Variations in length must be permitted if the entire billet is to be utilized. The physical properties of the product of the extrusion machine are dependent upon the mixture employed, but vary somewhat with the temperature of the material at the time it passes through the die. Cold drawing modifies these properties similarly to cold rolling.

Extruded bars may be used for structural purposes, in which case the standard tension test furnishes a measure of the quality. The stress-deformation diagram is, however, of such a character as to make the location of the elastic limit or yield point a matter of some refinement. They may also be used for forging stock, in which case workability becomes a factor of importance. The process is also extensively employed for making rods for use in screw machines (turret lathes). For this purpose, the ability to cut freely is essential and is governed by the mixture employed. Accuracy of dimensions, straightness, soundness, homogeneity and freedom from imperfections are also required. The rod is extruded slightly larger than the required size, cold drawn, straightened and cut to length.

Some mixtures cannot be either hot-rolled or readily extruded and must be cold-rolled or drawn. Usually the initial work is done by rolling and the final by drawing.

MANUFACTURE OF WIRE.

Wire is drawn from rods which may be either hot-rolled, cold-rolled or extruded, and afterwards drawn through dies by means of rotating blocks until the finished size is reached. The effect of cold drawing is similar to cold rolling so that annealing is required at intervals. Small sizes of rod are produced by straightening wire.

Variations in the characteristics of wire are produced precisely as in the case of sheet, by variations in mixture, amount of hard drawing and degree of annealing. No difficulty is experienced in keeping the diameter of wire within fairly close limits, as suitably-made dies do not wear with great rapidity.

MANUFACTURE OF SEAMLESS TUBES.

Seamless tubes are made by cold drawing from hollow cylindrical castings, by cold cupping from circular blanks and by modifications of the Mannesmann hot-rolling process. The latter method is employed to produce a hollow blank which is reduced to size by cold drawing. There are numerous advantages and limitations possessed by the various methods. The primary requirement for a good tube is a sound casting. The most difficult factor to contend with is that of concentricity of the inside and outside surfaces. This is subject to relatively large variations even within the same length, although the inside and outside diameters can be closely controlled.

Seamless tube is not usually employed for purposes requiring much distortion, that incident to bending being usually the most severe. Certain limitations to the degree of temper which it can possess, however, exist in a tendency possessed by hard tubes to crack spontaneously due to internal stress. Seamless tubes are used largely for purposes involving exposure to the action of corrosive agencies such as sea water, and under such circumstances exhibit the erratic behavior shown by other materials under like exposure. Much difference of opinion exists as to the ability to resist corrosion, or lack of it, imparted by variations in percentages of copper and zinc, and other ingredients usually accompanying these, as well as to the results of various manufacturing methods and processes.

THE RELATION OF QUALITIES TO USES.

From the considerations above discussed it will be seen that the problem of preparing rational specifications for wrought non-ferrous materials in various forms, and for various uses, is one involving many complex factors. It requires a comprehensive knowledge expressed in terms susceptible of definition and measurement of the qualities, which for any particular use are, on the one hand, necessary or desirable and, on the other hand, attainable. For example, it is possible to limit the presence of lead and iron always found in brass to quite low limits, and for certain purposes such limits are quite essential. There exists, however, a wide variety of uses which, to be most efficiently met, demand the presence of lead in varying amounts, while there are still other uses wherein it is neither beneficial nor harmful. Similarly, iron in considerable amounts may be advantageous, detrimental, or merely innocuous, according to the employment contemplated.

THE CONTROL OF QUALITY.

The difficulty of properly controlling the quality of material made in such small lots as to render impracticable the employment of suitable tests, physical or chemical, for each lot is, however, largely surmountable by the employment of appropriate mill practice and inspection. The test of manufacture is, in the case of cold-rolled or drawn material, capable of being made most severe. It has the exceedingly great advantage of application to an entire quantity, and not merely to a sample. No test of ductility, for example, can be more complete than that of drawing through a die, when the draft is properly chosen with respect to the ultimate ductility of the material operated upon.—"The Metal Industry."

PROCESS FOR PRESERVING IRON AND STEEL FROM CORROSION.

The coating of iron with zinc by hot galvanizing—that is, dipping the iron in molten zinc in combination with suitable fluxes; or cold galvanizing—viz: coating the iron or steel surface by electro-zincing—are the preservative processes that are most largely used by engineers. The reason that zinc, as a protective coating for iron and steel, has held its own for so long is that it is electro-positive to the underlying iron or steel, or, in other words, in the presence of moisture the iron and zinc form a galvanic couple, and as long as there is any zinc left in contact with the iron within a given area the zinc corrodes in preference to the iron, thus protecting it.

It is a well-known fact that the purer the iron is the less liable it is to pitting and corrosion, chemically pure iron being practically rustless. A new process, just brought out, termed "ferro-zincing" or "ironizing," turns these facts to account by coating the steel surface with almost pure iron, the only impurity of any significance being hydrogen. The addition of hydrogen is an advantage, for the reason that it makes the iron slightly more electro-positive to the underlying steel than it would otherwise be, so that it forms a better protective coating.

Another advantage of the coating of electrolytic iron is that the coating is homogeneous, and is not under unequal strain caused by mechanical operations such as drawing or hammering, and has not been subjected to any heat or mechanical treatment which of necessity causes impurities to be absorbed by the metal so treated.

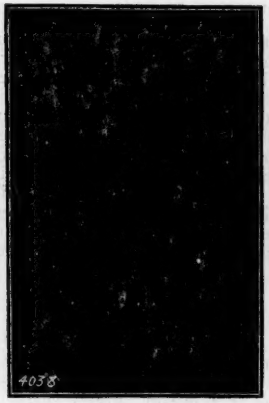

FIG. 1.

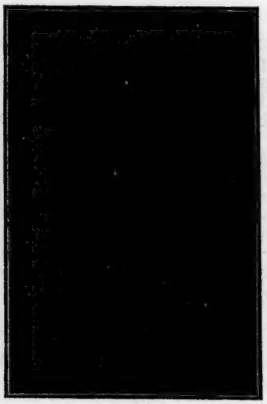

FIG. 2.

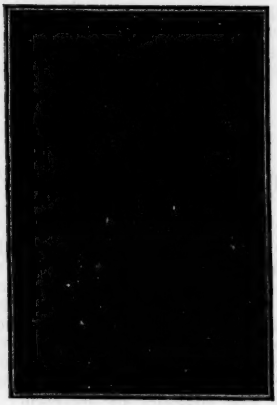

FIG. 3.

Fig. 1 is a photomicrograph of an ordinary steel surface, such, for instance, as mild-steel plate. Fig. 2 is a photomicrograph of an electrolytic iron surface which clearly shows the homogeneity of the latter as compared with the former. Fig. 3 shows an electrolytic iron-coated surface plated with zinc deposited electrolytically.

It is found in practice that it is advantageous to coat the electrolytic iron surface with zinc, as a zinc coating with an intermediate layer of pure iron hydrogen alloy gives a greatly increased life to an ordinary steel tube or plate for the reasons already given.

The inventor of the process—Mr. Sherard Cowper-Coles, of 1 and 2 Old Page street, Westminster, has granted a license to the British Mannesmann Tube Company for the protection of boiler tubes; and is applying the process to a number of other purposes.—"Engineering."

A NEW REAGENT FOR ETCHING STEEL, by Walter Rosenhain, B.A., and J. L. Haughton, M. Sc. Paper read before the Steel Institute, "Engineering," June 5, 1914. Illustrated with numerous micro-photographs.

MUNTZ METAL: The correlation of Composition, Structure, Heat Treatment, Mechanical Properties, etc., by J. E. Stead, D. Sc., F. R. S., and H. G. A. Stedman. "Engineering," June 5, 1914.

This article deals in detail with the composition, treatment, heating, annealing, etc, of this material. Illustrated with micro-photographs and diagrams

THE HARDENING OF METALS, by Professor C. A. Edwards, D. Sc., Professor of Metallurgy, Manchester University, and Professor H. C. H. Carpenter, M. A., Ph.D., Professor of Metallurgy, Royal School of Mines, Imperial College of Science and Technology, London. Paper read before the Iron and Steel Institute in London, reprinted in "Engineering," June 26, 1914. This paper deals extensively with the theoretical and practical problems involved.

This, taken in conjunction with reference immediately below, represents a comprehensive resumé of the latest information on this important subject.

A CONTRIBUTION TO THE THEORY OF HARDENING, by Andrew McCause, B. Sc., A. R. S. M. Paper read before the Iron and Steel Institute, May 7, 1914, reproduced in "Engineering," June 12, 1914.

This is an exhaustive paper on the subject of hardening metal. It deals first of the experimental investigation into the variations in the properties of steel of different carbon content with the temperature of quenching, and, second, with the theoretical inquiry into the actions taking place during quenching. The article is fully illustrated with diagrams, tables and photographs.

ADVANCES IN THE METALLURGY OF IRON AND STEEL, by Sir Robert Hadfield, F. R. S. A presidential address to the Faraday Society, June 11, 1914, reprinted in the "Engineer," June 26, 1914.

This article is largely historical, and gives the successive advances made and the famous names that have been connected with the development of metallurgy.

THE MAGNETIC AND MECHANICAL PROPERTIES OF MANGANESE STEEL.—Paper read by Sir R. A. Hadfield, F. R. S., and Professor B. Hopkinson, F. R. S., before the Iron and Steel Institute, May 7, 1914. Published in "Engineering" May 27, 1914.

This article gives the effect of various methods of heating and cooling as well as the magnetic and mechanical properties under different conditions. It is fully illustrated with photo-micrographs and diagrams.

AERONAUTICS.

AERONAUTICS.*

BY ALGERNON E. BERRIMAN, M. I. A. E., A. F. AE. S.

As members of an Institution directly concerned in the construction of Britain's first line of defence, you do not need to be told of the obvious importance of the aeroplane and the airship as engines of war. Potentially, they possess eyes to see the whole field of battle as clearly as if

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it were plotted on a map, and, potentially also, they have the power to strike from above.

At the present time, the navigation of the air is possible by the practical application of two distinct principles; buoyancy and dynamic reaction. The airship is an example of flotation by displacement, and is analogous to the ordinary displacement boat. The aeroplane, however, is sustained by the aerodynamic reaction of its wings, which act as deflectors of the relative wind in flight. It is analogous to the skimming boat or hydroplane. For voyages of very long duration and the transport of very heavy loads, the airship, in the present light of science, offers the greater

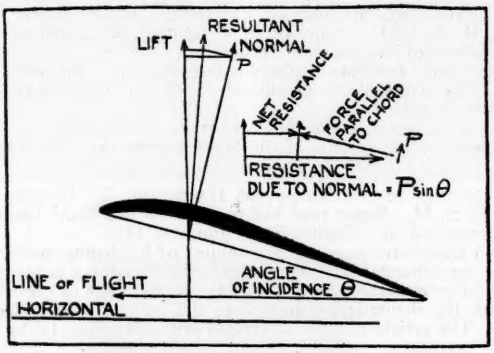


FIG. 1.—VECTOR DIAGRAM ILLUSTRATING THE FORCES ON A WING AS BUILT UP FROM THE DETAILS OF THE ANALYSIS OF FORCES.

theoretical and practical advantages. Long duration in the air in itself implies a heavy load of fuel apart from the useful load carried. With an aeroplane, velocity is involved as a factor in the support of the weight, and the problem of carrying very heavy loads economically by such machines is complicated for that reason. In the first place, the need to keep on flying at nearly full speed merely in order to remain aloft involves a minimum fuel consumption that might often be in excess of the requirements of an airship, which, in fine weather, would be able to economize considerably by cruising slowly, or even by remaining quiescent in the vicinity of the locality under observation. It is obvious that this quality is useful, and the more the pros and cons of aeroplanes and airships are considered the more it is apparent that both types of aircraft must necessarily be developed by any nation seeking to justify itself as a first-class aerial power.

I do not purpose entering into a technical discussion of the comparative problem represented by the very large dirigible and the very large airship. The very large airship, that is to say, very large compared with any aeroplane that has ever been constructed, is already an accomplished fact, and while aeroplanes will surely be built on a much larger scale than at present, their present size in relation to an airship is an object lesson that no student can afford to ignore.

The buoyancy of an airship is proportional to the displacement of its gas vessel, the approximate numerical equivalents being 1,000 cubic meters displacement per ton of load carried. This lifting force is derived from the relative lightness of hydrogen as compared with atmospheric air, and it has to support the material of which the containing envelope is made

and also the car in which the engine and passengers are carried. I have no exact data as to the ratio of net lift to gross lift for any specific ship, but approximately a 10-ton airship has a net lift of perhaps 3 tons, of which net lift a great deal will be earmarked for fuel. The duration of the journey is, of course, limited by the quantity of fuel carried, but there is another consideration in the leakage of hydrogen from the envelope, which, at present, prevents airships from remaining out indefinitely. In order to give some idea of relative sizes, I might quote H.M. Airship *Delta*, which has a gas vessel of 180,000 cubic feet, or slightly more than 5,000 cubic meters. Its gross lift is thus about 5 tons. The great rigid Zeppelins of the German army are each in the order of about 20 tons displacement, and such a ship has an overall length of about 450 feet.

In the military aeroplane trials of 1912, the heaviest aeroplane was the *Cody*, which weighed 1,948 pounds empty, and 2,680 pounds loaded with pilot and fuel and oil for 4½ hours' flight. Approximately, the useful load carried in the military aeroplane trials amounted to 700 pounds, varying with the fuel consumption of the engines employed. The lightest monoplane, a Bleriot, weighed 857 pounds empty, and 1,481 pounds loaded in flight.

The above figures I give merely in order to enable those who have not studied the subject at all some opportunity of fixing their ideas, and not in any way as an up-to-date compilation of exact values. They suffice to show that even a very small airship is a much larger craft than what we should regard as a very large aeroplane; and it is also equally clear that, on a comparison of weights in flight, the airship has already justified itself up to a size that is twenty times as heavy as the average aeroplane.

I have already said that I do not purpose discussing the technical problem presented by the large aeroplane in any great detail; at the same time it is my purpose to try and clearly emphasize the fundamental elements that underlie aeroplane design. Such aircraft are supported, as I have said, by the aerodynamic reaction of their wings. When the wing flies through the air, it disturbs a stratum of the atmosphere, and it is convenient, as an elementary conception of its action, to regard the wing as deflecting downwards a certain mass of air per second. From this downward acceleration, the wing will derive an upward reaction so long as the acceleration is maintained.

Actually, of course, the disturbance of the atmosphere is turbulent to a certain extent, and there are many interesting phenomena related to the distribution of pressure on a wing in flight.

Above the upper face of the wing there is a suction effect, and on the under side there is an increase in the air pressure above that of the atmosphere. About three-quarters of the total lifting force of the wing is derived from the action of the upper surface, and for this reason it is of fundamental importance that the profile of this part of the wing should be carefully chosen.

On account of the turbulence of the air flow over the wing the problem does not lend itself readily to mathematical treatment, but much progress has been made at the National Physical Laboratory at Teddington, by M. Eiffel in Paris, and at various other aeronautical laboratories, in the practical testing of model wing sections in a wind tunnel. This research is of a very technical character, for although the process of making the measurements is straightforward enough in itself, unremitting study and labor have had to be devoted to the construction of apparatus that is free from disturbing influences, and, in this country, the very greatest credit is due to the National Physical Laboratory for the work they have accomplished —work that places Great Britain on the highest possible level among contributors to the science of aeronautics. For the benefit of those unacquainted with official arrangements in this country I might perhaps explain that this research is conducted for the Government at the instigation of the Advisory Committee for Aeronautics, and the results are published

annually in a blue book. Full scale research proceeds on parallel lines at the Royal Aircraft Factory, the Superintendent of which—Mr. Mervyn O'Gorman, C. B.—has a seat on the Advisory Committee.

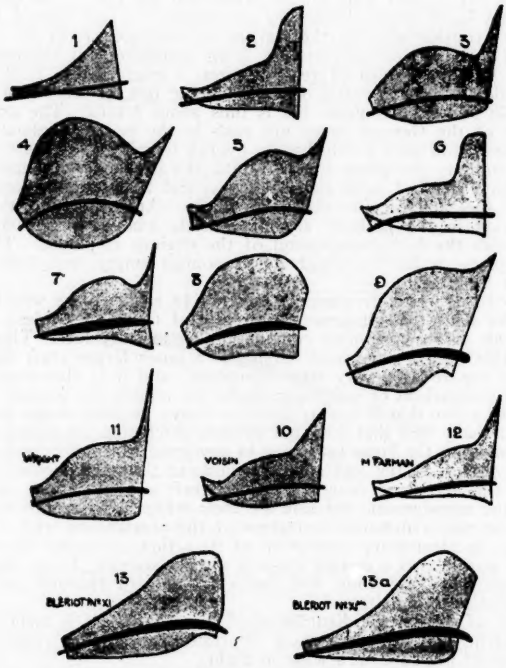


FIG. 2.—DIAGRAMS ILLUSTRATING THE DISTRIBUTION OF PRESSURE OVER VARIOUS WING SECTIONS INCLINED AT AN ANGLE OF 6 DEGREES INCIDENCE.

Reverting to the action of a wing in flight, the importance of the profile of the upper surface has been explained. Any flat plate flying at an angle to the relative wind will deflect the air, and will experience an upward reaction therefrom; but whereas the best of such flat plates will also experience a resistance of about 1 pound for every 7 pounds that it supports, a suitably cambered wing will support twice this load for the same expenditure of power. In the absolute, the lift per unit of surface will be proportional to the square of the relative speed so long as the wing maintains its attitude at the same angle. If the angle of incidence is changed the lift for a given velocity is also changed, as likewise is the ratio of the lift to the resistance.

There is an angle of least resistance, but its constant use implies flying always at one speed in order to support a given load with a fixed amount of surface. Every wing section has its own characteristic, and it is more important to select one that affords a reasonably wide speed range than

one that has a very high peak of what is sometimes called aerodynamic efficiency, but which I prefer to describe as the lift resistance ratio.

The speed range is a very important quality; indeed it may in some ways be regarded as *the* problem in the simple mechanics of flight. It is important that a machine should be able to fly slowly in order that it may more readily alight without damaging itself and more readily arise into the air from a confined space. It is also important that a machine should be able to fly fast, because in bad weather it is by its own superior speed that the machine conquers the wind, and journeys at last to its destination. A machine that is outpaced by the wind must drift, and sooner or later a forced descent will become inevitable. In military reconnoissance the fastest aeroplane is the safest from the enemy, and, therefore, the most likely to get home with its news. In sport, the fastest machine generally stands to win most prizes.

These opposite extremes of the speed range are concerned with two entirely different factors. High speed in the absolute depends necessarily on carrying sufficient reserve power to increase the velocity against an increasing resistance. Low speed in the absolute depends on a light wing loading. In short, the weight per unit of power and the weight per unit of surface should both be considered in a preliminary estimation of the probable ability of any given machine. I will not, however, suggest to you any empirical formula for the mathematical combination of these two factors, as an attempt that I once made myself in this direction convinced me that it is treading on dangerous ground. To think of very high speeds without bearing in mind the question of speed range is to ignore the very serious difficulty of safe starting and safe alighting, which is the crux of this problem. Pilots of exceptional skill manage to get on to the ground without damage at 70 or 80 miles an hour, but it cannot be regarded as a safe proceeding for the average man. It is especially difficult on water, where the resistance of the floats gives rise to a considerable upsetting couple, tending to trip the machine over on to its head. It is sometimes suggested that very fast machines might perhaps be built without the ordinary under-carriage, so that they could alight on their stomachs, so to speak. The trouble here is to know what to do with the propeller, which, when revolving, requires a certain amount of clearance above the ground. Doubtless a two-bladed propeller could be made to rest horizontally, but that in itself would not necessarily afford a complete solution to the difficulty.

My real reason for mentioning this matter is less on account of the general interest attaching to the problem itself than because of its being the one really significant difference between the aeroplane and the bird. The bird combines its propelling and supporting surfaces; in the aeroplane they are separate and distinct. The bird can glide like an aerial toboggan downhill, through the atmosphere on rigid outstretched pinions, and by merely flapping its wings it can supply the energy that otherwise it derives from the earth's attraction, and so can maintain horizontal flight indefinitely. On the upstroke of its wings, the bird does not experience, as was at one time supposed, a downward pressure thereon. During the upward movement, the wings are also advancing with the flight speed of the bird and so the relative motion is a slight slope to which the attitude of the wing can still preserve a positive angle of incidence. If, during the up-stroke, the bird advances its wing tips in front of its shoulders, the extra velocity may, in same measure, compensate for the diminution of angle caused by the wing rising. Conversely, during the down-stroke, the wing tip tends to retreat relatively to the shoulder, which in some degree neutralizes the superior lift due to the greater angle of incidence caused by its descent. Confusion of thought often arises over this relationship between the angle of incidence and the vertical movement of a wing in the air. If such motion in a vertical plane takes place while the wing as a whole also has a horizontal motion the net result is, of course,

an oblique motion, and it is with regard to this line of flight that the angle of incidence must be considered.

An interesting and important instance of this is the steadying effect of the wings of an aeroplane in flight. When a machine rolls, one wing tip descends and the other ascends. The descending wing tip has its angle of incidence thereby increased, for its flight path is obliquely downwards and its attitude in space unchanged. Conversely, the other wing tip has its vertical angle of incidence decreased while rising, the combined effect obviously creating a couple tending to check the initial disturbance. This damping couple exists only while this disturbance is maintained; it has no power to right the machine. In order to bring an aeroplane thus disturbed on to its proper level again, the angle of incidence of the two wings is altered by warping their surfaces. In order to enable this distortion to be used as a control, the rear wing spars are hinged to the body, and wires are attached to the extremities so that they may be raised or low-

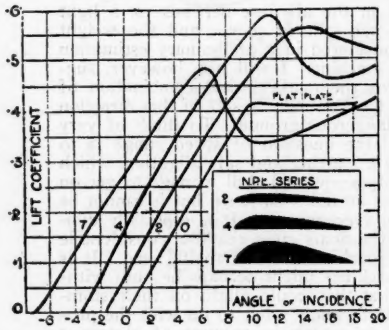


FIG. 3.—CHART COMPARING THE LIFTING EFFORT OF THREE FLAT-BOTTOMED WING SECTIONS AND A FLAT PLATE.

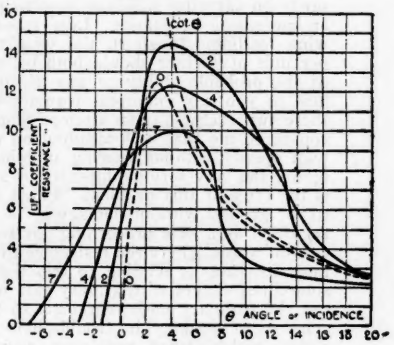


FIG. 4.—CHART COMPARING THE LIFT WITH THE RESISTANCE OF THE WING SECTIONS AND FLAT PLATE REFERRED TO IN THE PRECEDING DIAGRAM.

ered by moving a lever while the machine is in flight. The effect of lowering the extremity of one wing spar and raising that of the other is to alter the angle of incidence of the wing progressively from the shoulder to the tip. As the lift depends upon the angle of incidence, this creates a righting couple, and the machine rolls back into its proper position. Equally, the warp may be used to bank the machine when turning a corner, and generally for keeping it level in gusty weather. Sometimes hinged flaps are employed instead of warping the wings as a whole.

When the wings are warped, and also when flaps are used for this purpose, the machine tends to yaw from its axial course, owing to the difference in the resistance of the wing tips. In order to correct this yawing it is necessary to use the rudder simultaneously with the warp, and it is this combined action that constitutes the basis of the Wright patent, over which there has already been some litigation in America and abroad. The rudder as an organ of control promotes yawing; in itself, as I need hardly point out in the presence of an audience with a full knowledge of ships, it has no power to steer a course. The aeroplane, unlike the ship, however, has but a very slight setent of natural vertical surface in the form of a body, and unless it banks its wings at the turn, it will merely drift to lee-

ward under the action of the rudder. Inasmuch as yawing causes an acceleration of one wing tip and a deceleration of the other, the use of the rudder may indirectly promote a bank that will suffice for the purpose of turning, and some machines can be steered by this means alone. On others it is necessary to use the rudder and the warp simultaneously, on the Wright principle, with machines as they are at present constructed. It is necessary to point out in this connection, however, that the setting of the control that initiates the bank, will also maintain the roll, and if the control is held in that position too long, its effect will culminate dangerously in a side-slip. As the machine increases its bank so does it diminish the vertical component of its wing pressure, and it must, therefore, descend while turning unless the reserve power available suffices to increase the wing pressure by increasing the speed. Assuming that the maneuver of turning is to be carried out at constant velocity, there is thus a relationship between the angle of the bank and the appropriate slope of descent that will maintain an axial flight path in the banked attitude. If the machine is over-banked the mass of the machine will descend down a steeper slope than that along which its axis is pointing. In short, it will be said to sideslip inwards, and the condition is one that is fraught with danger. It is dangerous because the recovery into a position in which axial flight is reëstablished may require more altitude than intervenes between the machine and the ground. It is only possible to ensure a safe landing head to wind, and, of course, on level wings, so that the pilot is under the necessity of maneuvering his craft into that condition before he attempts to alight.

Apart from the question of the lack of altitude there is no real danger in any position that the machine may assume. Although this is strictly speaking true in theory, I dare scarcely have put it forward as a statement prior to the wonderful demonstrations of upside-down flying that have been given by Pegoud and Hucks. Their evolutions in the air really represent a highly scientific experiment, for they are a complete vindication of the fundamental principles of aeroplane design. They have shown in an absolutely conclusive manner that an aeroplane is controllable so long as it remains intact and so long as the pilot remains on board. Even if it capsizes it can be righted again without difficulty, as if nothing had happened, which is more than can be said of any other sort of craft. When a pilot flies upside down his machine is supported by the inverted wings, which are, of course, suitably braced to carry the weight of the machine in this position. As a matter of fact, the only difference between Pegoud's machine and the standard Bleriot monoplane is that the model flown by Pegoud has a taller mast above the pilot's cockpit, so that the stay wires to the tops of the wings may be at a less acute angle. The tail is larger than is ordinarily fitted to the single-seated Bleriot aeroplanes. When flying in their inverted position the wings are very "inefficient" aerodynamically. Their ratio of lift to resistance is low; the slope of gliding descent is, consequently, steep. During these maneuvers Pegoud is probably descending through the atmosphere at a higher rate of speed than the average express lift in a New York skyscraper.

On the subject of inverted flight Mr. F. W. Lanchester made an interesting communication to the British Association this year when he drew attention to a form of instability that he calls catastrophic. During some of his early experiments with models, which included the use of a simple flat sheet of mica with a small lead pellet in the center of its front edge, he found that, if disturbed, such flat plates, instead of recovering from the disturbance in the normal way, would sometimes recover into an inverted position and continue their flight in the opposite direction to that in which they were originally proceeding. It was as if they reached a critical position during the disturbance, from which they might be switched off, like a railway train, on to one track or the other. Ordinarily they would recover to their proper direction of flight, but occasionally they

would fly on inverted. Models that were looping the loop, for example, would now and again fail to complete the loop, and would, instead, fly on inverted from the top of the circle. Mr. Lanchester has shown that this quality of catastrophic instability is inherent in any design of machine that is capable of flying either way up without alteration of the elevator setting.

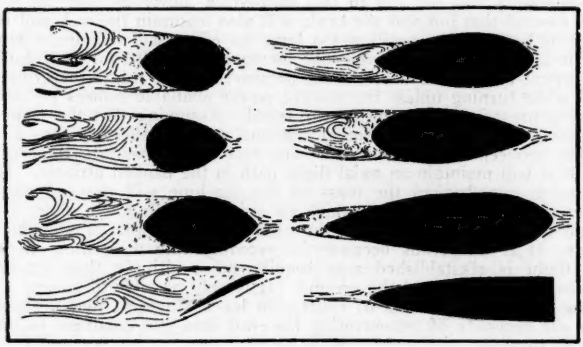


FIG. 5.—DIAGRAMS PREPARED FROM PHOTOGRAPHS PUBLISHED IN THE TECHNICAL REPORT OF THE ADVISORY COMMITTEE FOR 1912, SHOWING THE NATURE OF THE FLOW IN THE WAKE OF VARIOUS STRUT SECTIONS.

The flow is from right to left in the picture. The two lower diagrams show a wing section set at a steep angle of incidence, and the aft portion of a dirigible envelope. Immediately behind the obstruction in each case is a region of dead water. In this region there is not much turbulence, but the pressure is negative, and, therefore, adds to the resistance of motion. Further aft the fluid flow is more turbulent, as is indicated by the swirling lines. Where the above diagram is blank the flow of the fluid may be regarded as taking place in steady streamlines. Note the advantage of the longer sections in the two lower right-hand sketches.

Another machine that has been much in the public eye of late in connection with the stability problem is that designed by Mr. J. W. Dunne. Its characteristics include negative wing tips and the absence of a rudder. I have mentioned elsewhere that a rudder on any form of craft is only indirectly a steering organ. Primarily it promotes yawing, and it is due to the reactions that take place as a consequence of the spinning of the craft on its own vertical axis that the course of its motion is changed. If it were possible to bank an aeroplane by a true rolling motion about its axis, a proper steering force would be created and a rudder would be unnecessary. On the Dunne machine, this principle of control is obtained by differentiating the angles of the negative wing tips, and the important point in connection therewith is that this method of control does not tend to culminate dangerously. It is possible, in fact, to set the control levers that bank the machine and to leave them untouched while the aircraft continues to fly in a circle. The Dunne aeroplane has already performed a test of this character under the official observation of the Royal Aero Club.

Theories concerning the stability of aeroplanes are necessarily built up on some sort of hypothesis concerning the nature of a gust. Many of those who have invented stability devices appear to overlook the fact that in doing so they are unconsciously defining the weather with which they are attempting to deal, and I say "unconsciously" in this connection, be-

cause I have seldom observed any instance in which the inventor has troubled to explain the atmospheric conditions that he seeks to neutralize. When, some time ago, I started to devote my leisure to a consideration of the problem of equilibrium in the air, I set out in the first instance to try and define a plausible gust. I arbitrarily assumed that the smaller eddies in the air were individually negligible, and, therefore, I confined my attention to the idea of a moving mass of turbulent atmosphere having dimensions in space approximating to those of the aeroplane itself. On this assumption, it became apparent that the influence of such a gust on a machine already flying at a certain speed would be to alter the line of the relative wind in respect to the axis of the machine. In other words, the relative wind would veer or back according as the gust came from one side or the other. Similarly, if a gust came from above or beneath, the relative wind would alter its trend. In short, I came to picture the gust as an angular oscillation of the vector representing the relative wind.

Having arrived at these premises, which in themselves may be on debatable ground, the problem of lateral stability resolved itself into one of neutralizing the effect of this angular oscillation. Assuming that an oblique oscillation could be resolved into an angular motion in the horizontal plane, compounded with an angular motion in a vertical plane, I imagined that it would be possible to deal with these two components independently. In the horizontal plane an angular acceleration of the relative wind is analogous to spinning the machine about its vertical axis in calm air. In order to neutralize the canting effect of this spin it would suffice to make the tip of the wing negative, in order that the downward pressure thereon might neutralize the upward lift of the positive part of the wing. In this way I also arrived independently at the opinion that negative wing tips constituted a stabilizing principle, and I give the above argument as a personal explanation of what I believe to be their action on the Dunne aeroplane. With regard to the angular motion in the vertical plane, this is treated as a problem belonging to longitudinal stability, for which the relationship of the wing angle to the tail angle, known as the longitudinal dihedral, affords a practical solution.

I have of necessity led you to the vast domain of science in which equilibrium in the air is the central problem, and of necessity I must leave you on its threshold.—"Cassier's Engineering Monthly."

AEROPLANE ENGINES.

Six-cylinder, 120-H.P. water-cooled engine, constructed by Beardmore-Austro-Daimler Aero Engine Co., Ltd., London. Full illustration, description and details of this engine are given in "Engineering," May 15, 1914.

THE 200-HORSEPOWER CURTISS MOTOR FOR THE RODMAN WANAMAKER TRANSATLANTIC FLYER.

The 200-horsepower aeronautical motor for the Rodman Wanamaker trans-Atlantic flyer was given a five-hour run at moderate speed recently, and is said to have behaved well. As the motor had had but little limbering under shop power it has been thought advisable to keep the speed below 1,100 revolutions per minute for the first few days, but even at that speed the nine and one-half-foot experimental propeller shows a static thrust of more than 800 pounds.

The motor is of the Curtiss V-type, eight cylinders, with a bore and stroke of five by seven inches. The cylinders are individual, with welded

water jackets of non-corrosive Monel metal. Each cylinder has four tungsten steel valves two and one-fourth inches in diameter with seven-sixteenths inch lift. All thirty-two valves are operated from a single cam shaft. The cylinders are held down to the crank case by tubular studs from the heads with extension bolts passing through main bearing caps. All the outside bearings are self-lubricated with graphite.

The crank case is composed of two aluminum castings, thoroughly bridged. The crank shaft is four feet long, two and one-fourth inches diameter, and is drilled with an oil duct one and one-sixteenth inches diameter. It is made of imported Krupp steel. The connecting rods are I-type forgings with large bearings and oil ducts leading to the piston pins.

Water is circulated by large centrifugal pumps with double outlets. The cylinder heads and valve seats are water cooled, and the exhaust-valve stems are water cooled for almost their entire length.

Three rotary-gear pumps take care of the lubricating system. One large pump drives the oil under high pressure to every bearing through the main shaft, cam shaft and connecting rods; while two smaller pumps keep the lower half of the case drained. No splash system is employed, the idea being to eliminate the waste of oil and danger of flooding the cylinders should the machine assume an unusual angle.

The gasoline-intake manifolds are two and one-half inches in diameter and are water jacketed. Ignition at present is by two-spark magneto, but this may be replaced later by two single-spark instruments of the half-speed induction type.—"Scientific American."

THE SPERRY GYROSCOPIC STABILIZER.

HOW IT IS CONSTRUCTED, HOW IT OPERATES, AND HOW IT DEMONSTRATES ITS CAPABILITIES DURING AN INTERESTING TEST IN FRANCE.

By John Jay Ide, Paris Aeronautic Correspondent of the "Scientific American."

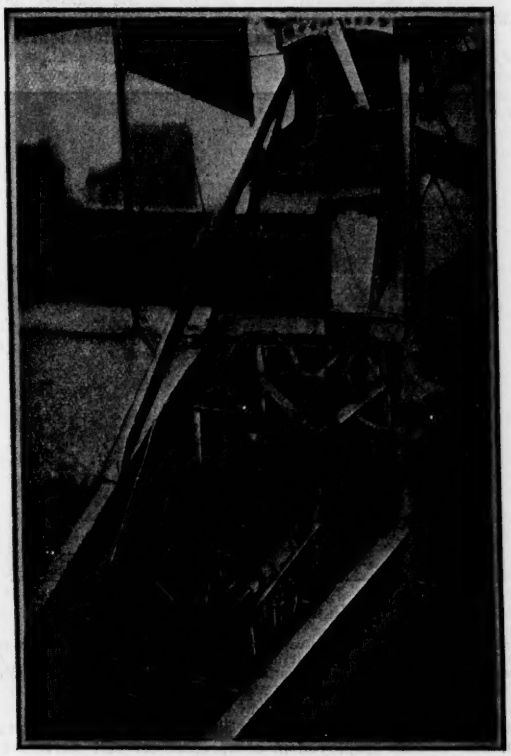
A description of the Sperry stabilizer for aeroplanes was given in the "Scientific American" for June 7th, 1913. Although the principle of operation remains the same, a number of changes in the construction have been made since that date. The stabilizer is now fitted to a Curtiss flying-boat instead of to the old-type hydro-aeroplane of the same make.

The apparatus proper consists of a group of four gyroscopes arranged in two pairs. The gyroscopes forming a pair revolve in opposite directions in order to neutralize precessional movement. One pair turns in the plane of symmetry of the aeroplane, and the other in the vertical plane parallel to the span. The group is contained in a sort of cage composed of two rings, one horizontal and the other vertical. The cage being universally jointed can oscillate around its lateral and longitudinal axes. Attached to the rings are levers acting on the valves of two compressed-air servo-motors, placed near the gyroscopes, controlling the elevator and ailerons. In normal flight the gyroscopes keep the axes of the rings strictly horizontal and vertical so that the slightest tipping of the aeroplane in any direction is instantly corrected through the servo-motors.

An essential part of the Sperry apparatus is the anemometer mounted on the right forward engine strut. The anemometer accomplishes three functions. In the first place it furnishes the pilot with a visible record of his speed at any moment. Secondly, it prevents the machine from rising so steeply that there is danger of its falling back on its tail. When the aeroplane approaches the critical angle the loss of wind pressure on

the rectangular disc causes the anemometer, by means of the servo-motor, to block the longitudinal control lever as regards further climbing by shifting its fulcrum. The aeroplane is then automatically started on a gliding descent which is continued until the normal flying speed is regained.

Finally, the anemometer regulates the action of the gyroscopes in turning. A certain angle of the aeroplane relative to the plane of the gyro-



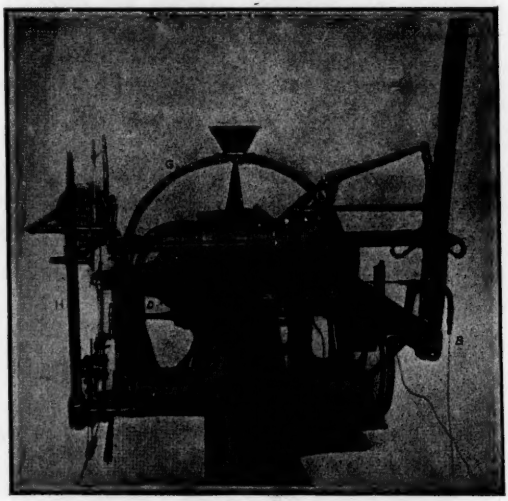
FRONT VIEW OF SPERRY STABILIZER.

Showing servo-motor at right and rear of gyroscopic group; regulator in front to the left; anemometer above attached to engine strut.

scopes entails a corresponding opening of the valve of the servo-motor, and consequently a corresponding angle of the ailerons or elevators as the case may be. As this angle depends upon the inclination of the aeroplane and not on its speed, the effect would vary greatly according to the velocity of the machine. A certain angle which would be suitable for low speeds would be much too great if the speed were high, and might even throw the pilot out of his seat. The anemometer by changing the fulcrums of the levers controlling the valves of the servo-motors according

to the wind pressure on its face insures that the corrective efforts of the ailerons and elevators are proportionate to the speed.

The electricity necessary for the gyroscopes, which weigh only two pounds each and turn at 12,000 revolutions per minute, is obtained from an alternating-current dynamo run from the front end of the motor by a belt. It is claimed that in case of stoppage of the motor the gyroscopes would continue revolving for half an hour. A battery, however, is carried as a reserve. A regulator, seen in one of the photographs in front and to the left of the apparatus, controls the current used by the gyroscopes. As the current is alternating, a wireless installation can be fitted with very little extra weight.



REAR VIEW OF SPERRY STABILIZER.

A, automatic lateral lever pivoted on valve-control crank; *B*, wire leading to supplementary control lever; *C*, control lever (lateral); *D*, gyroscope; *E*, inclinometer; *F*, cylinder of servo-motor; *G*, suspension ring; *H*, control lever (longitudinal); *J*, longitudinal control cylinder.

Compressed air is obtained from the motor and stored in a tank in a similar manner to that employed in compressed-air self-starters for automobiles. The tank is of sufficient capacity to supply the servo-motors for a short period after the stoppage of the engine. To get up pressure, however, the motor has to be run for a short period before a flight, and leakage is impossible to obviate entirely. In the stabilizers now under construction electric servo-motors are employed. The total weight of the apparatus is about 45 pounds.

Both lateral and longitudinal controls can be thrown in and out of action at the will of the pilot by means of a pedal. When the stabilizer is in action the ordinary means of control are completely blocked, but the direction of the machine can be changed laterally or longitudinally by small supplementary levers.

On Thursday, June 18th, at Bezons, near Paris, I saw the first demonstration before the committee of the Concours pour la Securité en

Aéroplane. During the flights Lawrence Sperry, the pilot, stood up with his hands above his head, abandoning all controls, while the mechanic left his seat and climbed out on the right wing, 6 feet from the longitudinal axis of the machine. As the passenger weighed 170 pounds, the upsetting moment was 1,020 foot-pounds. The first time this was done the aeroplane described a wide turn to the right owing to the extra head resistance, but on the second trial the machine kept its course perfectly, the pilot having set the rudder to the left before abandoning control. In neither case was the stability of the machine affected in the slightest degree, the ailerons automatically changing their angle of incidence so as to keep the aeroplane on an even keel.

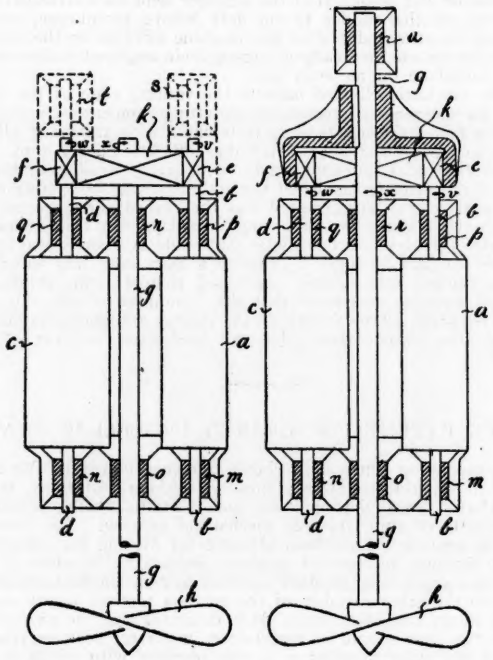
Later the mechanic climbed back to the trailing edge of the plane, and this time the elevators corrected the upsetting moment. By reducing the speed of the motor the flights were terminated with automatic glides down to the surface of the Seine. After these flights Sperry took up Commander Barres and Lieutenant Caylo successively to observe that he did not touch the control levers when the stabilizer was in operation.

The committee was so interested that they asked for a second series of tests, which took place the following Tuesday. On this occasion Réné Quinton, the president of the Ligue Nationale Aérienne, was carried as a passenger for half an hour. Although a high wind was blowing at the time, the aeroplane was entirely unaffected, thanks to the stabilizer. The tests indeed were so successful that the committee of the Concours has awarded first prize, 50,000 francs, to the Sperry automatic stability device. The grand prix, 400,000 francs, has not been won this year.—"Scientific American."

WEIR'S PATENT FOR GEARED PROPELLER SHAFTS.

The accompanying illustration shows a recent patent by Messrs. G. & J. Weir, Ltd., Engineers, Holm Foundry, Cathcart, Glasgow, for geared propeller shafts for ship propulsion, and it relates to the driving of the propeller shafts of ships through mechanical gearing. The prime mover employed to provide the mechanical work for driving the propeller shaft of a ship through mechanical gearing necessarily involves a rotating shaft, which carries one member of the gear—a toothed pinion—which engages with the other member of the gear—a toothed wheel—carried on or coupled to the propeller shaft. It is desirable that the axis of the one member of the gear should be maintained in correct position relatively to the axis of the other member, *i. e.*, the member with which it engages. It is desirable that, in the case of cylindrical or parallel-faced toothed-gear wheels, the axis of the driving pinion should be maintained parallel to the axis of the driven wheel with which it meshes to a very great degree of exactitude. This is especially the case when the intensity of tooth pressure is high, and the tooth velocity also high, which will generally be the case in the driving of the propeller shafts of moderate-sized and large vessels. It is desirable to so arrange the drive that the shaft carrying the driving pinion and the shaft carrying the driven wheel can in every case be readily put into and maintained in correct relative position, and this without involving the employment of elements of great weight. At present it is usual to provide bearings on each side of the pinion—and sometimes a middle bearing between the two portions of the pinion—and bearings on each side of the wheel, all these bearings being supported on, or rigidly attached to, the box which encloses the gear, or carried by members encircling this gear box. The relatively short distance between the bearings of either shaft, and the large diameter of the gear wheel employed with a large reduction ratio, render it difficult to maintain the pinion and wheel in sufficiently correct positions relatively to

each other. In this invention the propeller shaft is extended forward in the vessel alongside the prime mover, the gearing being placed at the forward end of the prime mover. Bearings are provided for the prime mover and propeller shafts at the forward end of the prime mover, and these bearings are rigidly connected together. Bearings are also provided for the prime mover and propeller shafts at the aft end of the prime



mover, and these bearings also are rigidly connected together. Both these sets of bearings can, if desired, be carried by or rigidly attached to the casing or non-moving part of the prime mover. Great rigidity can thus be obtained, while the relatively great axial distance between the bearings is very advantageous in arranging and maintaining correct alignment.—" Steamship."

WIRELESS TELEGRAPHY.—The " Engineer," June 5, 1914. Abstract of paper by H. Fothergill, read before the North-East Coast Institution of Engineers and Shipbuilders, April 23, 1914. Different Systems are described and compared. Well illustrated by diagrams.

NAVAL VESSELS.

UNITED STATES.

UNITED STATES NAVAL VESSELS UNDER CONSTRUCTION.

DEGREE OF COMPLETION.

No.	Vessel.	Building yard.	Engines.	No. shafts.	Speed, knots.	Percentage machinery completed 1914.		Hull com. Aug. 1, 1914. Per ct.
						July 1.	Aug. 1.	
	BATTLESHIPS:							
36	*Nevada*	Fore River S. Co.	Curtis turbine	2	20.5	78.23	77.70	72.4
37	*Oklahoma*	New York S. Co.	Reciprocating	2	20.5	78.38	80.43	72.6
38	*Pennsylvania*	Newport News Co.	Cur. trb. grd. cr.	4	21	33.28	36.25	42.0
39	*Arizona*	Navy Yard, N. Y.	Pars. trb. grd. cr.	4	21	10.71	13.05	24.4
	DESTROYERS:							
45	*Downes*	New York S. Co.	Curtis trb. & rec.	2	29	96.28	96.83	95.3
51	*O'Brien*	Wm. Cramp & Sons	Cramp trb. & rec.	2	29	76.11	80.81	79.0
52	*Nicholson*	Wm. Cramp & Sons.	Cramp trb. & rec.	2	29	75.10	77.76	73.3
53	*Winslow*	Wm. Cramp & Sons.	Cramp trb. & rec.	2	29	71.35	73.19	71.5
55	*Cushing*	Fore River S. Co.	Curtis trb. grd. cr.	2	29	66.10	67.65	56.1
56	*Ericsson*	New York S. Co.	Pars. trb. & rec.	2	29	66.93	69.81	76.9
57	*Tucker*	Fore River S. Co.	Curtis trb. grd. cr.	2	29.5	19.07	21.17	12.6
58	*Conyngham*	Wm. Cramp & Sons	Pars. trb. grd. cr.	2	29.5	14.60	16.91	11.1
59	*Porter*	Wm. Cramp & Sons.	Pars. trb. grd. cr.	2	29.5	13.27	15.24	9.0
60	*Wadsworth*	Bath Iron Works	Pars. trb. gearing.	2	30	43.57	53.60	48.4
61	*Jacob Jones*	New York S. Co.	Pars. trb. grd. cr.	2	29.5	20.98	25.13	14.9
62	*Wainwright*	New York S. Co.	Pars. trb. grd. cr.	2	29.5	20.98	26.79	14.4
	FUEL SHIPS:							
13	*Kanawha*	Navy Yard, Mare Isl'd	Reciprocating	2	14	48.90	54.20	71.2
14	*Maumee*	Navy Yard, Mare Isl'd	Diesel	2	14	...	...	35.4
	SUBMARINES:							
31	*G*-3	Navy Yard, N. Y.	Diesel-Sulzer	2	14	81.00	82.00	82.2
36	*K*-5	Fore River S. Co.	Diesel	2	14	99.26	99.26	98.8
37	*K*-6	Fore River S. Co.	Diesel	2	14	99.05	99.05	98.8
38	*K*-7	Union Iron Works	Diesel	2	14	99.15	99.84	94.3
39	*K*-8	Union Iron Works	Diesel	2	14	94.23	99.84	94.3
40	*L*-1	Fore River S. Co.	Diesel	2	14	81.45	84.58	49.3
41	*L*-2	Fore River S. Co.	Diesel	2	14	80.64	84.29	48.2
42	*L*-3	Fore River S. Co.	Diesel	2	14	61.81	83 30	47.3
43	*L*-4	Fore River S. Co.	Diesel	2	14	59.72	65.70	46.6
44	*L*-5	Lake T. B. Co.	Diesel	2	14	...	...	28.9
45	*L*-6	Lake T. B. Co.	Diesel	2	14	...	...	28.1
46	*L*-7	Lake T. B. Co.	Diesel	2	14	...	...	27.6
47	*M*-1	Fore River S. Co.	Diesel	2	14	71.94	78.05	33.1
48	*L*-8	Navy Yard Portsmouth.	Diesel	2	14	...	...	0.
49	*L*-9	Fore River S. Co.	Diesel	2	14	7.61	12.66	12.3
50	*L*-10	Fore River S. Co.	Diesel	2	14	7.61	12.03	12.3
	SUBMARINE TENDERS:							
1	*Fulton*	Fore River S. Co.	Diesel	1	12.25	91.31	93.57	81.4
2	*Bushnell*	Seattle Con. & D. D. Co.	Parsons trb. with gearing.	1	14	20.93	23.65	47.3
	DESTROYER TENDER:							
2	*Melville*	New York S. Co.	Parsons turbine with gearing.	1	15	22.36	34.53	59.7
	TRANSPORT:							
1	...	Navy Yard, Phila.	Reciprocating	2	14	*	*	0.
	SUPPLY SHIP:							
1	...	Navy Yard, Boston.	Reciprocating	2	14	*	*	0.
	TUGS:							
	Arapaho	Seattle Con. & D. D. Co.	Reciprocating	1	...	96.00	98.00	...
	Mohave	Seattle Con. & D. D. Co.	Reciprocating	1	...	87.00	90.00	...
	Tillamook	Seattle Con. & D. D. Co.	Reciprocating	1	...	79.00	84.00	...

*No report.

K-3 and *K*-4 have completed their preliminary trials at Seattle, Wash.

THE *NEVADA* AND *QUEEN ELIZABETH* COMPARED.

To the Editor of the SCIENTIFIC AMERICAN:

I noticed in one of your recent publications remarks by Mr. C. P. Slosson, San Francisco: the comparison of the British *Queen Elizabeth* and United States *Nevada;* also remarks on speed of British battle-cruisers. I also noticed your answers to said remarks. Now if you will permit me, I would like to say a few words. In the first place, I may say it has always been a very great pleasure to me to read your valued paper. A Britisher naturally likes fair play, and I am sure the "Scientific American" puts a thing fairly and squarely before the public. Of course, in making a comparison it is only fair to compare contemporary ships. Now, take into consideration the four great events or essentials in a war-ship, viz: speed, radius of action, gun power and defensive armor. Of course, the British ship has the advantage, a great advantage, in speed. In radius of action, as both ships are to use oil fuel exclusively, and as reliable data are not at hand, I cannot say for sure as to which has the advantage on that point. In gun power we have ten 14-inch guns with 1,400-pound shell, and 2,600 foot-seconds; energy, 65,606 foot-tons on the *Nevada*. Eight 15-inch guns with 1,950-pound shell, 2,500 foot-seconds; energy; 84,510 foot-tons on the *Queen Elizabeth*. Here we see the British ship, although carrying fewer guns, throws a heavier weight of metal at a discharge with a greater energy, which would be more effective at long range. The weight of the American gun is 63.1 tons. The weight of the British gun is 96 tons; both 45 calibers long. In defensive armor or qualities of defense the principal interest in the *Nevada* class is their great defensive power and the armor has been, or will be, so disposed to a greater advantage than on any ship hitherto built, at least from the American standpoint. From a British standpoint the armor is so disposed on the *Queen Elizabeth* to the greatest possible advantage; the armor on both is about the same maximum thickness, so in recapitulation we have *Queen Elizabeth*, greater speed; *Queen Elizabeth*, greater gun power; *Queen Elizabeth*, at least equal defensive power; *Queen Elizabeth*, questionable radius of action. You cannot put a quart of power in a pint of displacement, and as both displacements are about the same, for the displacement given of British ships are their displacements when in commission with full load of stores, ammunition, etc., but with normal coal capacity, I take it that British designers have turned out the better ship, more especially as the cost per ton is less in the case of British ships. Take for instance contemporary ships *Neptune* and *Delaware*. The British *Neptune* works out $418 per ton. The United States *Delaware* works out about $450 per ton. The British ship *Lion* worked out at $382 per ton.

W. R. SHUTE in "Scientific American."

THE SUBMARINE TENDER FULTON.

DESCRIPTION OF THE FIRST SUBMARINE TENDER BUILT FOR THE UNITED STATES NAVY—DIESEL ENGINES INSTALLED.

There is now nearing completion at the works of the Fore River Shipbuilding Corporation at Quincy, Massachusetts, the first submarine tender for the United States Navy. This vessel, named the *Fulton*, is from the designs of the New London Ship and Engine Company, of Groton, Connecticut, by whom her engines were also designed and built. She is of interest, not only as being the first of a new type of vessel, but also as being the first large vessel for the Navy equipped with Diesel engines.

The *Fulton* was launched June 6 and christened by Mrs. Alice Crary

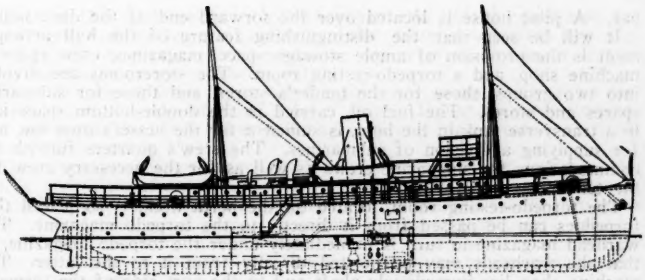


FIG. 1.—OUTBOARD PROFILE OF THE DIESEL-ENGINED SUBMARINE TENDER "FULTON."

Sutcliffe, the great-grand-daughter of Robert Fulton, for whom the vessel is named. Unlike most naval ships, the *Fulton* was built to merchant specifications, and when in service will be the mother ship for a division of submarines.

The principal dimensions of the vessel are as follows:

Length, over all, feet and inches	226–6
Beam, feet	35
Draft, load, feet and inches	12–11½

The crew consists of about 190 officers and men.

The object of the design has been to furnish a vessel for an auxiliary to submarines, which may accompany them and carry necessary fuel, stores and ammunition, and which may, at the same time, be able to perform routine repairs to their machinery and outfit, and to charge their air flasks, storage batteries and fuel tanks. For this reason the military features of the design have received minor attention, and all possible weight and space have been devoted to storerooms, oil tanks and machine shops. As it is necessary for the tender to carry fuel oil for the submarines, it is desirable that she also use the same fuel for propulsion, in order to obviate the necessity of storing two kinds of fuel—oil and coal. This object might, of course, have been attained by using either a steam plant with oil-burning boilers or oil engines. The latter were chosen on account of their much greater fuel economy, which gives greatly increased carrying power with the same radius of action. The space required for propelling machinery is also materially reduced.

GENERAL ARRANGEMENT.

The vessel is of the flush-deck type, with two principal decks—the upper deck and the berth deck, and with partial platform decks at the ends. Upon the deck is a deck house. There are two pole masts with derrick booms.

The hold contains the chain locker, storerooms, warhead and ammunition magazines and fuel tanks. The main engines and auxiliary boiler room are located amidships. On the platform deck are storerooms and torpedo magazines forward, and crew's space aft. On the berth deck are crew's quarters and petty officers' quarters aft, machine shop amidships, and torpedo-testing room and wardroom quarters forward. In the deck house are located the commander's cabin, offices, galleys and sick

bay. A pilot house is located over the forward end of the deck house.

It will be seen that the distinguishing feature of the hull arrangement is the provision of ample stowage space, magazines, crew space, a machine shop, and a torpedo-testing room. The storerooms are divided into two groups, those for the tender's stores, and those for submarine spares and stores. The fuel oil, carried in the double-bottom space and in a transverse tank in the hold, is sufficient for the vessel's own use, and for supplying a division of submarines. The crew's quarters furnish accommodations for submarine crews as well as for the necessary crew for the tender.

The torpedo-testing room, located on the berth deck, is so placed that torpedoes can be passed from it directly to the torpedo magazine. The warhead magazine in turn is immediately under the torpedo magazine, so that the warheads may be hoisted directly from it to the latter. The machine shop lies immediately abaft and to the port side of the torpedo-testing room about the engine hatch. This grouping of the torpedo rooms and machine shop together facilitates tests and repairs. The machine shop is equipped with lathes, shapers, drill presses, milling machines, and the other necessary machine tools for repairs to the engines and auxiliaries of the submarines.

The sick bay is of large size, with separate bath, dispensary and laboratory, in order that it may care for sick or injured from both the submarines and the tender. It is located in the deck house, in a light and airy position.

As the main engines are of the internal-combustion type, it was desirable to stall an auxiliary boiler for supplying steam to the heating system and for driving such auxiliaries as the anchor windlass, the steering engine, towing machine, and the evaporator plant, which cannot well be driven by electricity. The boiler room is located in the hold, forward of the engine room, and, besides the boiler, contains feed pumps, distiller circulating pumps, sanitary pumps, air pumps, all of which are steam-driven, condenser, feed-water heater, evaporator and distiller. The boiler is equipped to burn fuel oil. This steam plant, being merely an auxiliary, is of comparatively small capacity, and creates only a comparatively small drain on the fuel supply, especially as it need be run at full power only under exceptional cases.

PROPELLING MACHINERY.

On account of its novelty probably the most interesting feature of the vessel is the main propelling machinery. This consists of a single vertical, inverted, two-cycle, single-acting air-starting and reversing oil engine of the Diesel type, with six working cylinders and two air compressors. The shaft horsepower delivered is about 1,000 at about 260 revolutions.

Fig. 2, which shows the engine on the test stand gives a general idea of the arrangement. The six working cylinders and two air compressors are on the same fore-and-aft line, the air compressors being at the forward end of the engine, where is located the control station. The engine is entirely controlled, starting, stopping, changing speed, and reversing, through a hand wheel at this station. The pistons are of the stepped type, the upper part forming the working piston, and the lower the scavenging piston. From the scavenging cylinder the scavenging air at low pressure is carried to an external receiver, whence it goes to the working cylinders, and overboard through the exhaust. This arrangement of scavenging cylinders has the advantage that any leakage of gases from the working cylinder, due to leaky piston rings, passes into the scavenging air, with no possibility of escaping into the engine room. In addition the crank pit is entirely enclosed. In larger engines now under construction it has been found desirable to use an open crank-case form of construction, but for

engines of this speed with forced lubrication, the closed crank-case has advantages, and as large, quickly-removable crank-case covers are provided, which may be removed while the engine is in motion, it is free from the disadvantage of inaccessibility.

Each working cylinder is provided with two scavenger valves, an air-starting valve, a spray valve and a relief valve. The spray valve atomizes and injects the fuel into the cylinder by means of high-pressure air from the air compressors.

The scavenger valve is connected to the scavenger-air receiver. All valves are driven from a cam shaft carried in bearings on top of the cylinder heads. This cam shaft is driven from the crankshaft through a vertical shaft and spiral gears. A special feature is a pneumatic cylinder which, when reversing, automatically places the cam shaft in the proper position relative to crankshaft, before air is admitted to the cylinders for starting the engine.

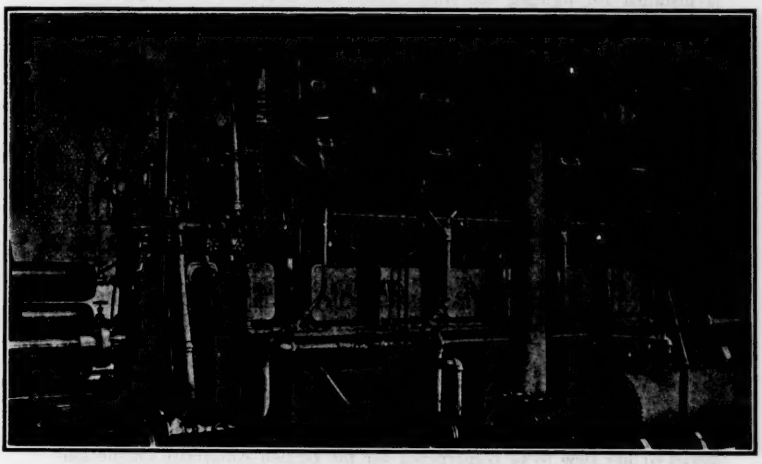


FIG. 2.—THE "FULTON'S" 1,000-HORSEPOWER DIESEL ENGINE ON THE TEST STAND.

The wrist pins are of large size, giving very moderate bearing pressures, and located in the scavenger piston, where the temperatures are low. The scavenger cylinder acts as a crosshead guide, and is water-cooled. A novel feature is the use of fresh water for cooling the pistons. Water is carried to the pistons through pipes with swinging joints, so that a continuous circulation of fresh, cool water is insured. The lubrication is of the pressure type, lubricating oil being supplied by a small lubricating-oil pump. The cylinders and cylinder heads are water-cooled by a salt-water system independent of the fresh-water system above mentioned.

AIR COMPRESSORS.

The air compressors are two-stage, and supply air for spraying the fuel and for charging the starting flasks. The cylinders and heads are water-jacketed, and the air is passed through cooling coils after the first and second stages. The air flasks are also connected to the independent ship's high-pressure air line, so that air may be drawn from the latter in emergency.

The pumps form two independent motor-driven units. Each unit consists of a centrifugal salt-water pump, a rotary fresh-water pump, a rotary lubricating-oil pump, and a rotary fuel-oil pump. One unit is sufficient for the engine at full power; the other being a stand-by. The rotary fuel pump takes suction from the oil-storage tanks, and discharges to a gravity-feed tank in the engine hatch, whence the fuel flows to the measuring pumps on the engine. These pumps discharge the oil in the proper measured quantities for the power desired. A direct-driven governor positively controls the quantity of oil discharged by the measuring pumps, and hence the power delivered.

The electric plant is of considerable size, as the tender is designed to be capable of charging the batteries of submarines in addition to supplying its own electrical needs. There are two generators, driven from the forward end of the main engine crankshaft. A small turbo-driven generator is installed for lighting the ship. There are also two motor-driven air compressors of sufficient capacity to charge torpedoes or the air flasks of the submarines. A small low-pressure air compressor is installed for supplying air to pneumatic tools.

Taken all in all, it appears that this vessel promises to be a very useful accessory to our submarine flotilla. It will be a step towards the elimination of the makeshift mother ships for submarines, the use of which has been rendered necessary by the lack of vessels especially designed for such service.—"International Marine Engineering."

ENGLAND.

CONSTRUCTIONAL FEATURES OF THE TORPEDO-BOAT DESTROYER *ARDENT*.

Messrs. William Denny & Bros., Dumbarton, have recently handed over to the British Admiralty H.M.S. *Ardent*, a torpedo-boat destroyer of 24,500 I.H.P., one of eight special vessels, for the design of which the firms contracting to build them were responsible to the Admiralty. Other properties apart, the *Ardent* is notable from the fact that she is the first vessel of her type to be constructed for the British Admiralty on the longitudinal principle. Her design, proposed by the builders, was accepted by the Admiralty and developed in detail by the builders' staff in close collaboration with Whitehall. Unlike other vessels built on the longitudinal principle—with wide-spread, strong, transverse frames and beams, combined with longitudinal framing, and where the frames are scored over the longitudinals in the usual Isherwood design—the frames in the case of the *Ardent* are carried out to the shell direct, and the longitudinals are cut at each frame and bulkhead, being fished at the frames by short pieces of angle passed through holes inside of the line of the shell angles on the deep frames. This produces a very strong combination where the wide-spaced frames, as in this case, are necessarily of limited depth. At the bulkheads the longitudinals are connected by knees on each side, thus dispensing with a great deal of collar work usually associated with destroyers.

The *Ardent* passed through all her trials successfully previous to delivery, except the usual "rough-weather" trials. After a delay of ten days without suitable weather occurring the vessel was handed over. The rough-weather trial has since taken place in ordinary service, the vessel being subsequently docked and examined, when she was found in perfect order. Her local strength will, it is anticipated, be more fully recognized by the results obtained under actual service conditions.

No attempt was made in this, the first experiment in applying the longitudinal principle of construction to torpedo-boat destroyers, to take the fullest advantage of the system in respect to economy of material, but in vessels of destroyer proportions there should be decided scope for development. The credit of introducing the improvements already effected, and, in future, possible, should be made clear at this stage. Messrs. William Denny Bros. and licensees of Mr. J. W. Isherwood, of the "Isherwood longitudinal framing system," on which, generally speaking, the construction of the *Ardent* has been based; but in addition to this, constructional features are embodied which have Sir Archibald Denny, Bart., as their author.

NEW YARROW DESTROYERS.

H.M.S. *Miranda,* building by Yarrow & Co., Ltd., of Glasgow, for the British Admiralty, was successfully launched at the firm's yard.

This vessel, one of the three special destroyers ordered from Yarrow & Co., Ltd., of their own design, is 260 feet long by 25 feet 7 inches beam. The contract speed is 35 knots, and the vessel is fitted with Yarrow's latest type of water-tube boilers and superheaters, by which a considerable economy in fuel is obtained.

It is intersting to note that H.M.S. *Miranda* is the first vessel to be launched of the 1913–1914 program known as the "M" class.

H.M.S. *Landrail,* the fourth torpedo-boat destroyer of the 1912–1913 program, built by Yarrow & Co., Ltd., of Glasgow, was handed over to the British Admiralty on the 10th instant.

This vessel, which is 260 feet long and 27 feet 6 inches beam, is propelled by turbines, the steam being supplied by three of Yarrow's latest type of water-tube boilers of same general type as fitted on *Miranda.*

LIGHT CRUISER CONSTRUCTION.

Of the eight light-armored cruisers authorized in the 1913–14 naval program, one was launched and three begun during February, all in the public dockyards. The *Cordelia* was put afloat at Pembroke on February 23d, the naming ceremony being performed by the Hon. Venetia Stanley, daughter of Lord Sheffield. On February 25th, the *Carysfort* was laid down on the same slip at Pembroke. The *Cleopatra* was begun at Devonport on February 26th, and the *Conquest* at Chatham, about the same time, although the ceremony of laying the first keel plate did not take place until March 2d. These cruisers will have a displacement of about 3,450 tons, a length of 420 feet, an extreme breadth of 39 feet, and a mean load draught of 12½ feet. Their turbine engines will be of 30,000 horsepower, which are to give a nominal speed of 30 knots, but this is expected to be exceeded on actual trial and service. Oil fuel only will be burned under the boilers. The armament will consist of three 6-inch guns, of which two will be mounted on the upper deck aft and two on the forecastle deck, and six 4-inch guns, mounted in the central part of the ship, three on either broadside.

AUSTRALIAN SUBMARINES.

On May 25th, the first two submarines for the Royal Australian Navy arrived at Sydney. They had made the voyage from England in twelve weeks under their own motive power. This is the longest journey ever made by submarines under such conditions. The smaller British boats sent to China early in 1911, *C.36, C.37,* and *C.38,* only proceeded as far as Malta using their own engines, and were towed from thence to Hong-Kong by cruisers. The Australian vessels, as mentioned in the "Journal" for February last, are of the *E* type, with a submerged displacement of

800 tons as compared to the 321 tons of the *C class*. They were commanded during the voyage by officers of the Royal Navy, lent for duty under the Australian Government, *AE.1* being under the command of Lieutenant Commander T. F. Besant, formerly in command of *C.30* at Dundee; and *AE.2* under the command of Lieutenant H. H. G. D. Stoker, formerly commanding *B.8* at Gibraltar. From Portsmouth to Colombo the boats were convoyed by the *Eclipse*, Captain F. Brandt, from Colombo to Singapore by the *Yarmouth*, Captain H. L. Cochrane, and from Singaport to Sydney by the Royal Australian cruiser *Sydney*, Captain J. C. T. Glossop. It was during the time that Admiral Sir Dilmot Fawkes was Commander-in-Chief in Australia (from 1905 to 1908) that arrangements were made for sending men from the Commonwealth to qualify in the British naval schools, including that of the submarine branch, and it is owing to this forethought that a large proportion of the crews of the two new boats are Australians.—"J. R. U. S. I."

AUSTRIA-HUNGARY.

THE *SZENT ISTVAN*.

As recorded last month, the battleship *Szent Istvan*, the fourth Austrian Dreadnought, was launched at Fiume on January 17th. The following particulars relating to her design appeared recently in the "Glasgow Herald": All the 12-inch guns have an arc of fire of 300 degrees. The ammunition carried consists of 130 rounds for each of the 12-inch guns, 200 rounds for each of the 5.9-inch guns, and about 2,000 rounds for the quick-firers. There are three 18-inch torpedo tubes. Protection is afforded by a belt of armor 11 inches thick amidships, and 4¾ inches at the ends, the turret armor being 12 inches thick, and the protection to the secondary guns six inches thick. The *Szent Istvan*, like her three sister ships, is equipped with triple turrets. "Competent critics agree," said the writer in the "Glasgow Herald," "that Austria has produced in the four vessels of this class ships of very fine design. For fighting power, in speed, and in their ample protection, they are probably unexcelled by any other battleships afloat of the same displacement." The class has a displacement of 20,000, and was designed in 1909. It is stated that the prolonged building period for the *Szent Istvan* has enabled many improvements to be made in the details of her equipment, so that she will be more up-to-date than her sister ships.—"J. R. U. S. I."

THE FOUR NEW BATTLESHIPS.

In regard to the four new Dreadnoughts for Austria-Hungary it is stated that two will be laid down in the present year and two in 1915. The months of August and October are mentioned for the beginning of the first two, but the 1915 ships will be laid down in the spring. A significant feature of their design as at present revealed is that the method of distributing the heavy guns has been changed from that in the *Viribus Unitis* class, and instead of four triple turrets there will be five twin turrets. That the caliber of the heavy guns has been raised from 12-inch is certain, but it is not known definitely whether the new weapons will be of 14-inch or 15-inch caliber. Anti-aircraft guns are also to be carried in the new vessels.

OIL ENGINE TRIALS.

It is reported that the torpedo-gun vessel *Lussin* has been experimentally fitted with heavy-oil engines for propulsion. She is the first vessel of the Austrian Navy to be equipped with internal-combustion machinery, apart, of course, from submarines, although the surface propulsion of the latter is by petroleum motors. The *Lussin* is an old vessel, built at Trieste in 1883, and has a displacement of 1,011 tons. Originally she was fitted with horizontal compound steam engines of 1,830 horsepower, giving a maximum speed of 14 knots, the boilers being on the Dürr pattern. The nature or power of the heavy-oil motors which have now been given to her for trial have not been disclosed.—"J. R. U. S. I."

BRAZIL.

A THIRD DREADNOUGHT.

Having disposed of the battelship *Rio de Janeiro* to Turkey in accordance with the decision arrived at in October, the Brazilian Government has announced its intention to have built a larger vessel in her place. A Reuter telegram from Rio de Janeiro on May 11th stated that the new ship would be of 30,000 tons and carry 15-inch guns. The contract was to be signed shortly, added the message, by the Minister of Marine and a representative of Messrs. Armstrong, Whitworth and Co., who were the builders of the *Rio de Janeiro*.

NEW SUBMARINES.

There have been launched at the Fiat-San-Giorgio yard at Spezia three submarines for the Brazilian Navy. They are the first under-water vessels yet built for Brazil. The type is similar to that of the Italian submarine *Medusa,* which is of 241 tons on the surface and 295 tons when submerged, and has engines of 600 surface horsepower giving a speed of 13 knots. The Brazilian boats, however, are somewhat larger, their displacement, on the surface being 249 tons, and submerged 370 tons, while they are reported to have a surface speed of 14 knots. Each boat has two torpedo tubes.—"J. R. U. S. I."

CHILE.

THIRD DESTROYER LAUNCHED.

Of the group of six large ocean-going destroyers which the Chilian Republic ordered of Messrs. J. S. White & Co., Cowes, in September, 1911, the third has now been launched. This is the *Almirante Simpson,* which took the water on February 26th. The naming ceremony was performed by Senora Cuevas, wife of the Secretary to the Chilian Legation. The first two destroyers of the class, named after Admirals Lynch and Condell, have been completed and sent to America. These destroyers are the largest yet built for any Navy, except for the *Swift,* the British special type vessel.

FRANCE.

NEW LIGHT CRUISER DESIGN.

A change, attributed to motives of economy, has been made in the design of the three light cruisers which it is proposed to build as part of the 1914 program. Instead of the 6,000-ton vessels projected after the maneuvers off Toulon last year, which would have cost £760,000 each, three vessels of 4,500 tons are now preferred, to cost £560,000 each. The smaller type is known as a "conducteur d'escadrilles" or flotilla cruiser. Some delay is reported to be inevitable, owing to the change of plans, in the beginning of the three scouts.

GERMANY.

NUMBERS OF PERSONNEL.

In the German Navy Estimates for 1914, the sum total of the personnel of all ranks is given as 79,080, being an increase of 6,191 over the figures for the previous year. The detailed figures for the various grades are as follows:

.....	Officers.	Warrant officers.	Petty officers.	Seamen.	Boys.	Total, all ranks.	Increase compared with 1913.
Naval officers	2,388	...	...	...	...	2,388	139
Junior executive officers	...	...	448	245	...	693	50
Engineer officers	585	...	...	...	...	585	48
Seamen, boys, dockyard and torpedo division	...	2,447	13,376	47,218	1,950	64,991	5,000
Seamen artillery	...	185	1,042	5,116	...	6,343	955
Marine infantry	52	...	208	1,122	...	1,382	161*
Clothing department	2	...	32	150	...	184	1
Medical department	340	...	366	438	...	1,114	77
Artillery administration	123	167	70	...	...	369	18
Torpedo personnel	78	173	71	...	...	322	14
Mining personnel	44	64	89	...	...	197	10
Accountant department	...	115	285	80	...	480	36
Surveying department	...	32	...	...	...	32	4
Totals	3,612	3,183	15,996	54,369	1,950	79,080	6,191

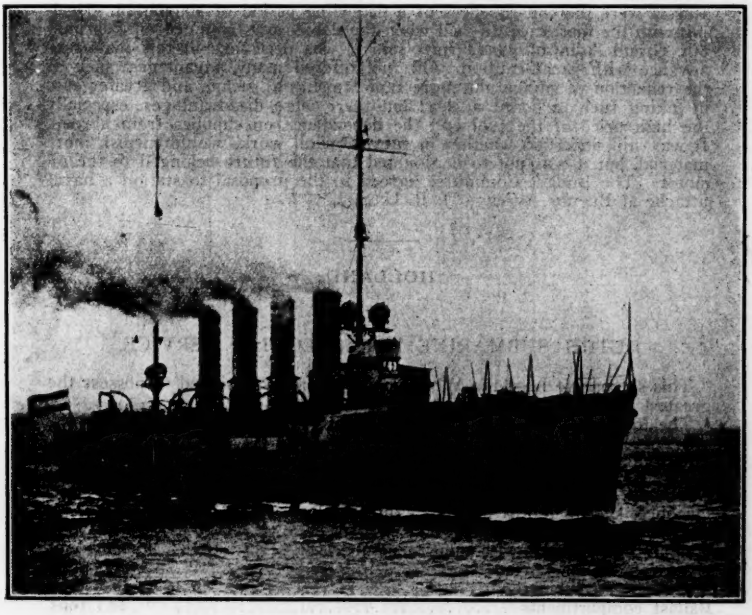
* Reductions.

THE GERMAN DREADNOUGHT *KRONPRINZ.*

The *Kronprinz* was launched on February 21st from the Krupp Germaniawerft, was laid down in 1912, and will take her place in the high sea fleet in the summer of next year. She will have a displacement of 27,000 metric tons and will carry ten 12-inch 50-caliber guns, all on the center line in five turrets, the penultimate pairs firing over the forward and aft pairs; fourteen 6-inch guns of 50 calibers, and twelve 3.5-inch guns of 45 calibers, as well as two machine guns. Her torpedo armament will consist of five 20-inch tubes, four on the broadside and one at the stern. Her protection will be 14 inches thick for the turrets and belt and 16 inches for the conning tower. She will be propelled at 23 knots by turbines of 35,000 horsepower, and will cost in round numbers 50 million marks—say, 2½ million pounds sterling—of which 30 million marks will be spent on the hull 18,700,000 on the guns, and 1,370,000 on the torpedo armament.—"The Engineer."

THE *KARLSRÜHE.*

The *Karlsrühe* and the *Rostock* are improved vessels of the *Breslau* type. They are of 4,900 tons displacement, while the *Breslau* is 4,550 tons. The *Karlsrühe* was placed in service January 15, 1914, and the *Rostock* February 6, 1914. The time between their launching and being placed in service was 14 and 15 months respectively.



"KARLSRÜHE."

These vessels are 139 meters long, 13 m. .7 beam, and have a draught of 5 m. .20.

They have 14 Schultz boilers, oil-burning. The speed of *Karlsrühe* is said to be 29 knots. She carries twelve 105 mm. guns and two under-water torpedo tubes.—"Le Yacht."

NAVY ESTIMATES DISCUSSION.

Speaking in the Budget Committee of the Reichstag on February 4th, Grand Admiral von Tirpitz dealt with the relative naval strength of Great Britain and Germany, and said that "the relationship of sixteen to ten offered by England was today still acceptable, though, on the other hand, the holiday year mentioned on the occasion of an election speech could not be realized." He stated that during the past five years the outlay for naval purposes had increased in Germany by £2,750,000; in England by £10,800,000, or four times as much, without counting the Supplementary Estimate of about £3,000,000 that was to be expected; in France by £6,700,000, or two-and-a-half times as much; and in Russia by £15,100,000, or five-and-a-half times as much. Answering questions, the Grand Admiral said that Germany had never set the pace in the increase of displacements and calibers, and never would do so. Commenting in the "Berliner Tageblatt" on the figures of Grand Admiral von Tirptiz, Captain Persius pointed out that the period of five years had been carefully selected, and took no account of the fact that the increases in France and Russia were the consequences of a preceding period of stagnation. Dealing with the matter of oil fuel when the debate was resumed on February 6th, Grand Admiral von Tirpitz said it was necessary in this matter to advance with great caution. Oil fuel offered many advantages, such as the reduction of smoke, the more rapid raising of steam, and greater ease in taking fuel on board at sea; but there were disadvantages, especially the high price of the fuel and the dependence on supplies from abroad. It was still uncertain whether in future tar-oil works would furnish more material, but it was not to be doubted that the future belonged to the oil motor. The Budget Committee agreed to the proposal to station a naval attaché at Buenos Ayres.—"J. R. U. S. I."

HOLLAND.

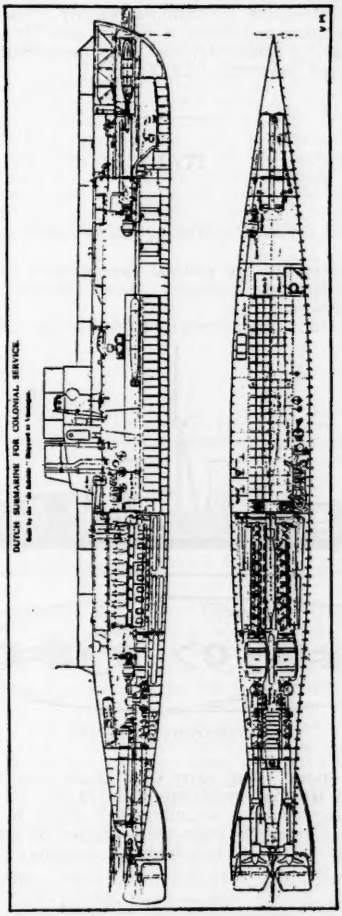
DUTCH SUBMARINE FOR COLONIAL SERVICE.

This submarine is of the Whitehead type and is designed to possess the greatest possible submerged speed.

The following are the general dimensions:

Length, over all	43 m. 52 cm.
Beam	4 m. 32 cm.
Depth	3 m. 64 cm.
Distance, keel to top of superstructure	4 m. 24 cm.
Height of freeboard	74 cm.
Height of freeboard with superstructure	1 m. 32 cm.
Displacement, on surface	338 tons
submerged	386 tons
Ballast compartments	52.7 tons
Fuel-oil compartments	16.1 tons
Torpedoes	4 tons

The surface engines are two-cylinder Diesel, double-acting, of 450 H.P. each, which give a speed of 16 knots above water. The submerged propulsion is obtained from storage batteries driving electric motors of 325 H.P. each. The capacity of the accumulators is 3,830 ampère-hours, which will give a speed of 11 knots for one hour or 8 knots for 4 hours.



The designs call for three main ballast compartments, disposed at the bow, the stern and amidships. The conning tower is surrounded by a fairwater designed to give the least possible resistance to the movement of the vessel. Special arrangements are made for ventilating the vessel. The central station has two periscopes, a steering wheel and all the necessary equipment for maneuvering the vessel.

There is also a submarine bell and an installation of telephones. An electric galley is provided.

The armament consists of three tubes, two forward and one aft. There are three torpedoes in the tubes and three stowed near the tubes.

There are horizontal rudders at bow and stern, also vertical rudders operated by hydraulic mechanism.

The vessels are designed for colonial service. Thanks to the double hull and the frigeration apparatus, it will be possible to keep cool.

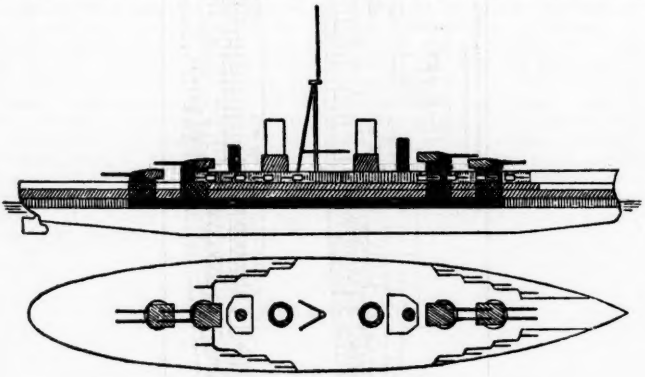
There are numerous safety devices. The metacentric height awash is 420 mm.; submerged 393 mm.—"Le Yacht."

ITALY.

CRISTOFORO COLOMBO.

We reproduce herewith the general arrangement of the new Italian armored vessels *Cristoforo Colombo, Marc-Antonio-Calonna, Canecciola* and *Francesco-Morosini.*

These vessels have a displacement of 26,000 tons; length, 211.5 meters,



"CRISTOFORO COLOMBO."

and a speed of 25 knots. They carry eight 38-cm. guns and sixteen 15-cm. The armor belt is 340 mm. amidships and 170 mm. at the ends, and the main belt is surmounted by a secondary belt which is believed to be 170 mm. in thickness. The smoke pipes are protected by armor 150 mm. thick at their base. The vessel is exclusively oil burning.—"Le Yacht."

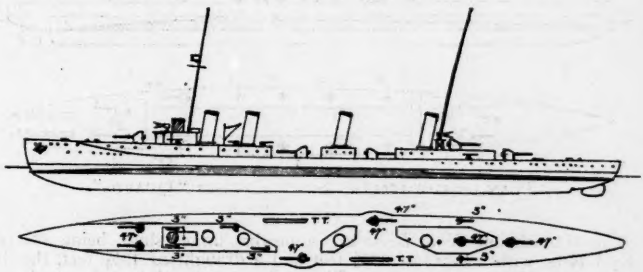
ITALIAN SCOUT CRUISERS *MARSALA* AND *QUARTO.*

The study of Italian warship designs is always interesting, inasmuch as they may be said to represent the direct antithesis of our own. For while we are content to provide moderate gun power on a displacement which

should assure good sea-going qualities, the Italians aim at the heaviest offensive qualities in combination with the highest speed and the lightest possible hull.

At times British ships fall short of the ideal aimed at. The "Town" class might be cited as a case in point. Their armament is good, they steam well, and the coal supply is sufficient, but they are bad sea boats, rolling excessively and generally uncomfortable, besides making difficult gun platforms in anything like heavy weather.

Hitherto the Italian constructors have produced almost uniformly successful ships. The *V. Emanuele* class, famous for their weight-saving girder construction, carry a couple of 12-inch and twelve 8-inch guns on a displacement of 12,625 tons, and are new steaming better than ever, easily maintaining 22 knots. Likewise the Dreadnoughts *Dante Alighieri* and *Cavour* classes have high speed, a heavy-gun provision, and moderate protection, with good sea-going qualities. A set-back seems, however, to have been experienced with the new scouts of the *Marsala* and *Quarto* types, and from all accounts they are far from being good sea boats. In them too much has been attempted upon the displacement; either this, or else the lines are faulty—probably the former, as the trial speeds were attained in good weather.

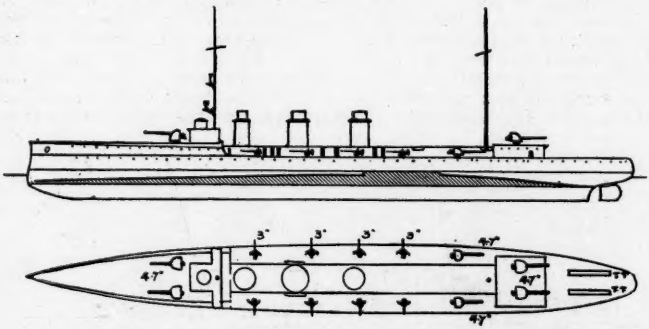


PLAN OF THE ITALIAN SCOUT CRUISER "MARSALA."

The two ships differ considerably in design, the *Quarto* being the sole representative of her type, while two of the *Marsalas* are finished and a third either building or projected. In each the armament is the same, viz: Six 4.7-inch and six 3-inch guns, with two torpedo tubes, but from the plans it will be seen that whereas in the former ship the guns are disposed to give arcs of fire on one side only, the latter has her amidships guns *en echelon* so that they can be brought to bear on either broadside. In addition, while the bow of the *Quarto* is slightly curved forwards ram shape, the *Marsala* has a convex stem, well cut away from the water line to the keel. The difference is accentuated in their profiles, the *Quarto* having three short bolt-upright funnels, and the others four narrow raked smoke stacks, peculiarly spaced.

The *Quarto* was laid down at Venice on November, 1909, launched in August, 1911, and completed for sea last year. She displaces 3,300 tons, her dimensions being: length (b.p.), 417 feet, beam, 42¼ feet, and draught (mean), 13 feet. Her complement is 197 officers and men. The 4.7-inch guns are placed in pairs on the forecastle—which has a slight whaleback—amidships, athwart of the main mast, and on the superstructure over the poop. The fore and aftermost pairs have the same command, but the amidships guns are a deck lower. Three 3-inch guns are spaced amidships on either side, while the two torpedo tubes are mounted in the

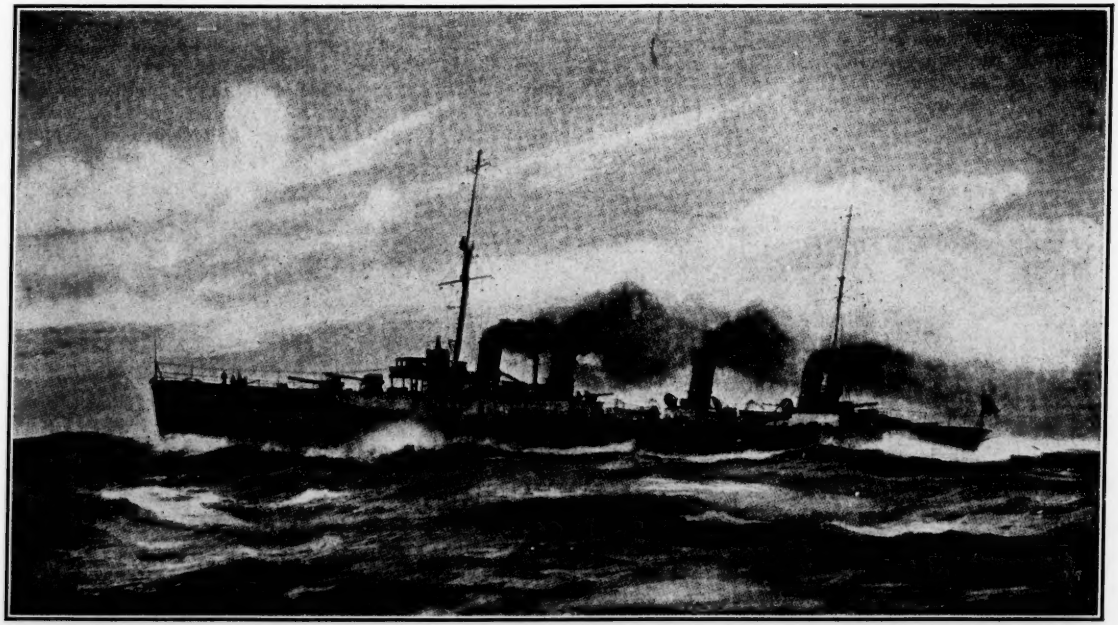
stern. These discharge the 18-inch weapon. Driven by Parsons turbines of 25,000 designed H.P. she easily reached 28 knots to trial (max. 29.5 knots), steam being generated in ten Blechynden boilers,—she being the third Italian ship to be so equipped. In the past Belleville, Babcock and Niclausse boilers have held the field, but both in the *D. Alighieri* and *San Giorgio* the Blechynden has given excellent results. On trial she used oil fuel only, of which 450 tons was the normal and 800 tons the maximum storage. The furnaces, however, were seemingly a source of never-ending trouble, and accordingly the liquid installation was removed and coal substituted, both in the *Quarto* and the other two ships. Details as to the fuel capacity now are wanting.



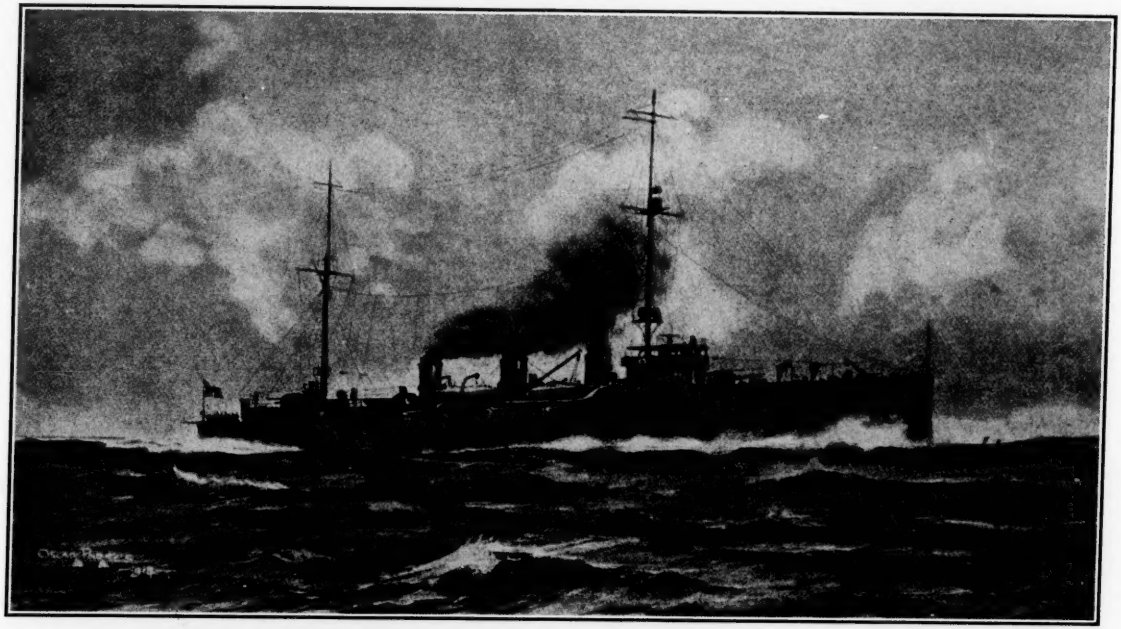
PLAN OF THE ITALIAN SCOUT CRUISER "QUARTO."

The *Marsala* and *Nino Bixio* are somewhat larger ships, being 431 feet (b.p.) long, with a beam of 42½ feet and a draught of 13¼ feet, the displacement rising to 3,470 tons. The guns are placed two forward, two amidships diagonally, the port being forward, and two aft, one on the raised deck and the other on the quarter deck. The positions of the 3-

	Type.	Displ., tons.	I.H.P.	Speed.	Armament.	T. tubes.	Coal.	Launch.
England.....	*Falmouth*.....	5,250	25,000	25	8 6-inch.	2	750—1,000	1910
	Active.....	3,360	18,000	25	4 smaller. 10 4-inch.	2	450—600	1911
Austria.....	*A. Spaun*.....	3,500	20,000	26	7 3.9-inch. 2 smaller.	3	450—850	1909
Brazil.....	*Bahia*.....	3,000	18,000	26.5	10 4.7-inch. 6 smaller.	2	650	1908
Germany.....	*Augsburg*.....	4,281	19,600	25.5	12 4.1-inch. 2 smaller.	2	400—900	1909
Italy.....	*Quarto*.....	3,300	25,000	28	6 4.7-inch.	2	(?)	1911-12
	Marsala.....	3,470	22,500	28	6 smaller.	2	(?)	
Japan.....	*Yahagi*.....	4,950	22,500	26	6 6-inch. 4 3-inch. 4 smaller.	2	600—850	1911
U. S. A.....	*Salem*.....	3,750	16,000	24	2 5-inch. 8 3-inch.	2	475—1,200	1907



ITALIAN SCOUT CRUISER "MARSALA."



ITALIAN SCOUT CRUISER "QUARTO."

inch guns are best seen from the plan; their arrangement gives them wide arcs of fire with but little interference. The torpedo tubes are situated one on each side, amidships. Owing to her greater length and finer lines, the horsepower is not so much as in the previous ships; Parsons turbines of 22,500 designed H.P. give a speed of 28 knots. She has fourteen boilers (Blechynden) instead of ten, and the oil-fuel supply was originally 400 to 1,000 tons before the conversion to coal. Both ships were built at Castellamare and laid down in 1911; the *Bixio* was put afloat in December, 1911, and her sister in March, 1912, while both were completed last year. The protection of all the ships consists of a 1¼-inch steel deck, and the larger guns have thin shields.

Previous to the laying down on the *Quarto* cruiser construction had been at a standstill in Italy—as in most other countries; no small ships had been built after the *Puglia* (1898), the fleet scouts having been the rebuilt torpedo-gunboats. The renaissance of the unarmored cruiser having been practically universal, it is interesting to compare these Italian ships with their contemporaries in other countries.

It will be seen that they are smaller than their possible opponents, they have a higher speed, are as powerfully armed—or more so,—and possess a more general fuel supply. Their weak point is undoubtedly in their bad sea-going qualities, as with the exception of the British "Town" class the other types are reported to be good sea boats.

The menace of the new Austrian scouts will be met by the construction of a 5,000-ton type (*Carlo Mirabello*) armed with 6-inch guns, but full details of these are as yet lacking.—"The Marine Engineer and Naval Architect."

DESTROYER TRIALS.

Some creditable performances have been made by the new Italian 600-ton destroyers. The *Audice*, built by the Orlando firm at Leghorn, developed a maximum speed of 36.2 knots, with 20,000 horsepower. This class was only designed for 30 knots, with 15,000 horsepower. Oil only is used as fuel. The completion by the Orlando Company of the four boats of the "*A*" class, and by the Pattison Company of the six of the "*I*" class, increases the number of Italian destroyers to 32, all the boats being under 15 years of age.

REPAIR OF THE *SAN GIORGIO*.

Reports from Taranto, where the cruiser, *San Giorgio*, is being repaired after her grounding in the Straits of Messina in November last, state that the vessel, while considerably damaged, is not permanently injured, and credit is given to those responsible for the salvage operations for the efficient manner in which they carried out their difficult task. Not only had the cruiser to be lightened to the extent of 1,500 tons by the removal of guns and turrets as well as coal and stores, but dynamite had to be used against a rock on which the bow was wedged.

NEW LIGHT CRUISERS.

According to the Italian correspondent of the "Naval and Military Record," a new type of light cruiser is to be built, the first of which will be laid down before the spring. The displacement will be 5,000 tons, and the designed speed 27.5 knots. A thin water-line belt and strong protective deck will be features of this class, while special attention will be given to seaworthiness, and the scantlings will be much stronger than those employed in the *Quarto* and *Nino Bixio*.—"J. R. U. S. I."

HEARD ON THE "MID-WATCH" BELOW.

STILL ANOTHER KIND OF MARINE.

A Provincetown fisherman has the profoundest respect imaginable for a submarine sailor. This is exemplified in the following, which was overheard on the dock while some mechanics were doing work on a damaged propeller which caused remarks typical of the profession, and may have made the surrounding atmosphere blue.

"Are those men sailors or marines?" asked a grizzled old man, the hero of many a race to Boston with a load of fish.

"Well," answered his companion, drawing regularly at an old clay pipe, "they don't fear the Lord, they don't fear the devil, and they don't care what the other people think. I guess they must be some of these here ultra marines."—(Contributed).

AN ECHO FROM THE CAM-SHAFT NAVY.

The boat is late this week because our gasoline engine got a cranky streak. The more we cranked it the crankier it got. We unscrewed the umbilicus and took out the trajectory. This seemed to be all right, and we concluded that there might have been a leakage of the synovial fluid through the pyloric orifice into the appendix. We had a deuce of a time removing the appendix with a monkey wrench and a cold chisel. There was nothing in it. There is a pipe that runs from the engine through the stern of the boat into the atmosphere; we had noticed that when the engine was running this pipe said "kapunk" every time the clapper on the engine said "kapeet." We examined the kapunker and found that a mermaid had stuffed a dead eel in it. This solved the mystery. The engine couldn't "kapeet" because the kapunker couldn't "kapunk." An athsmatic condition caused by insufficient evaporation of the jagoline in the fryingheater was removed by swabbing the throat of the needle valve with an extract of beef, iron and wine. Now the boat would surely run. But no, nothing doing. There was then but one remaining element that had been left alone. It was the spark producer. By an application of Woolsey's Formula "Q," the correct gap was determined, and after interpolating between O and a few times it was set. And that's why we are here.—(Modified) with due apologies to *Motor Boating*.

TESTS.

"Professor, we'll have to send this coal down to Georgia and have it weighed," said the student at work on a coal-analysis test.

The professor's batting average on humor was about 0.030. "Certainly not!" he declared. "We have the best balances in the country in our laboratory."

"Well, it's written here plainly enough: 'Coal must be weighed in a dry state.'"

MERCHANT VESSELS.

THE *AQUITANIA*, NEW CUNARD LINER.

The vessel and machinery are fully described in "Engineering," May 8, 15 and 29. This description of a large Parsons directly-connected turbine installation is of special interest on account of the elaborate detail of various parts that is given. The machinery, both main and auxiliary, is fully described.

It is greatly regretted that no fuel or water-consumption data is given.

THE HAMBURG-AMERIKA LINER *IMPERATOR*.

"Engineering," June 12, 1914.—This vessel and its machinery is fully described and illustrated. This vessel has a displacement of 57,000 tons; shaft H.P., 61,000; speed designed, 22.5 knots (23.96 said to be realized in service); fitted with Curtis A. E. G. Vulcan turbines arranged on four shafts, there being one H.P., one I.P. and two L.P. turbines. Backing turbines are fitted on each shaft, these being a H.P. and a L.P. astern turbine on each side of the vessel. Yarrow boilers fitted with Howden draft supply steam at 228 pounds pressure.

THE GEARED TURBINES ON THE *CAIRNROSS*.

Last week-end, the Newcastle steamer *Cairnross*, the first cargo steamer to be propelled by geared turbines, arrived in the Tyne after a round voyage of 57,000 miles. The vessel, since leaving the builders' yard at Sunderland in January of last year, has made voyages to the East Indies, Montreal, Calais to Newport, Canada, and then, via the Cape to Australia and New Zealand, returning home by Cape Horn. Her owners, officers and engineers all appear to be highly satisfied with the performances of the engines. We learn from the master (Captain Hyslop) that the vessel encountered some very rough weather, and that the engines gave entire satisfaction at such times. There was a more regular rate of speed, no "racing," very little vibration and a marked absence of noise. The economy in coal consumption, estimated at 15 per cent. during the comparative trials of the *Cairnross* and *Cairngowan*—the latter fitted with ordinary triple-expansion engines—early last year appears to have been fully maintained during the 57,000-mile voyage. An interesting point in connection with the vessel has been the economy in the use of lubricating oil, only 80 gallons having sufficed for the *Cairnross's* long journey. The method by which the lubrication is carried out is that the oil comes down from a tank placed above the engines and is distributed to the various bearings of the machinery, from which it runs into another tank. It is then pumped back into the gravity tank and, in that way, about 500 gallons of oil are in constant circulation.

OBITUARY.

SIDNEY LE. SMITH.

By Geo. W. Baird, Rear Admiral, U. S. N. (Retired).

Sidney Le. Smith, late First Assistant Engineer, U. S. N., died at Grove Hall, Mass., on the 27th of May.

Mr. Smith entered the Navy in October, 1861, as a Third Assistant Engineer, from purely patriotic motives. He was possessed of a competent fortune before entering the service.

His first duty was on board the *Kearsarge,* where he remained three years, and was in that little ship during her memorable encounter with the Confederate cruiser *Alabama,* and was the last surviving officer of that battle.

He was promoted to Second Assistant Engineer in August, 1863.

His next ship was the *Winnipeg,* the first steam practice ship for a class of midshipmen at the Naval Academy, where it had been decided to teach engineering and applied mechanics at the Academy.

His next duty was at the Academy as an instructor, where he served from April, 1866, to October 1867, when he was sent to the *Powhatan,* flagship in the Pacific, where he remained until December, 1869, when he was detached, promoted to First Assistant, and remained on waiting orders until July, 1870, when he was sent to the ironclad *Dictator* in the Atlantic Fleet.

He served in the Bureau of Steam Engineering from October, 1871, until the following January, when he was sent to the Washington Navy Yard on experimental duty, and, on April 18, 1873, he was sent to the Flagship *Worcester* where he remained three years. He served in the Kittery Navy

Yard from May, 1871, to July, 1879, when he was again ordered to the *Powhatan,* flagship of the Atlantic Fleet, and transferred to the succeeding flagship *Tennessee* the following December, and on the completion of the cruise (three years) was ordered to the Boston Yard, where he remained until December 2, 1882, when he was given a year's leave of absence. This ended his active service in the Navy, up to which time he had to his credit eleven and a-half years of sea service, six and a-half years of shore duty and two and a-quarter years unemployed. His resignation was accepted to take effect from August 29, 1884.

Mr. Smith's merit was obscured by his modesty and diffidence. He was a reticent man, a habitual student and a Christian gentleman. He loved life in the Navy and was fond of all engineering; he was popular on board ship, though never a leader in social entertainments. His wants were few and he was abstemious to a fault. His financial holdings and responsibilities had increased so as to require more attention than he could give them while at sea, which was the cause of his resignation. He was a member of this Society.

ASSOCIATION NOTES.

THE FOLLOWING MEMBERS AND ASSOCIATES have joined the Society since the publication of the last number of the JOURNAL:

MEMBERS.

Barroll, Henry H., Commander, U. S. Navy, Retired.
Benson, Howard H. J., Ensign, U. S. Navy.
Bieg, Valentine N., Ensign, U. S. Navy.
Bouson, Herbert H., Ensign, U. S. Navy.
Brown, Stuart S., Ensign, U. S. Navy.
Bruce, Bryson, Lieutenant, U. S. Navy.
Bye, Levi B., Lieutenant, U. S. Navy.
Connor, Edward H., Lieutenant, U. S. Navy.
Cutts, Edwin F., Lieutenant, U. S. Navy.
Emmett, Robert R. M., Lieutenant, U. S. Navy.
Esler, Jay K., Ensign, U. S. Navy.
Frellsen, Raymond F., Lieutenant, U. S. Navy.
Grayson, Robert H., Ensign, U. S. Navy.
Hanson, Ralph T., Assistant Naval Constructor, U. S. Navy.
Hatch, Frederick S., Ensign, U. S. Navy.
Herbster, Victor D., Lieutenant, U. S. Navy.
Hooper, Stanford C., Lieutenant, U. S. Navy.
Hutchins, Charles T., Lieutenant, U. S. Navy.
Jensen, Henry M., Lieutenant, U. S. Navy.
Joyce, Myles, Lieutenant, U. S. Navy.
Lee, William H., Lieutenant, U. S. Navy.
Logan, Edgar A., Lieutenant, U. S. Navy.
Lowell, Robert T. S., Lieutenant, U. S. Navy.
Maloney, James D., Ensign, U. S. Navy.
Perham, Herbert N., 3d Lieutenant of Engineers, U. S. R. C. S.
Roberts, Chester S., Ensign, U. S. Navy.

Skelton, Robert H., Ensign U. S. Navy.
Starr, Fletcher C., Lieutenant, U. S. Navy.
Stevens, Lemuel M., Lieutenant, U. S. Navy.
Stirling, Archibald G., Lieutenant, U. S. Navy.
Toaz, William H., Lieutenant, U. S. Navy.
Young, Robert T., Ensign, U. S. Navy.

ASSOCIATES.

Baker, Earl E., care of Eckliff Automatic Boiler Circulator Co., 33 Broadway, New York City.
Parker, Charles H., Assistant Superintendent, Generating Department, Edison Company of Boston, 39 Boylston Street, Boston, Mass.